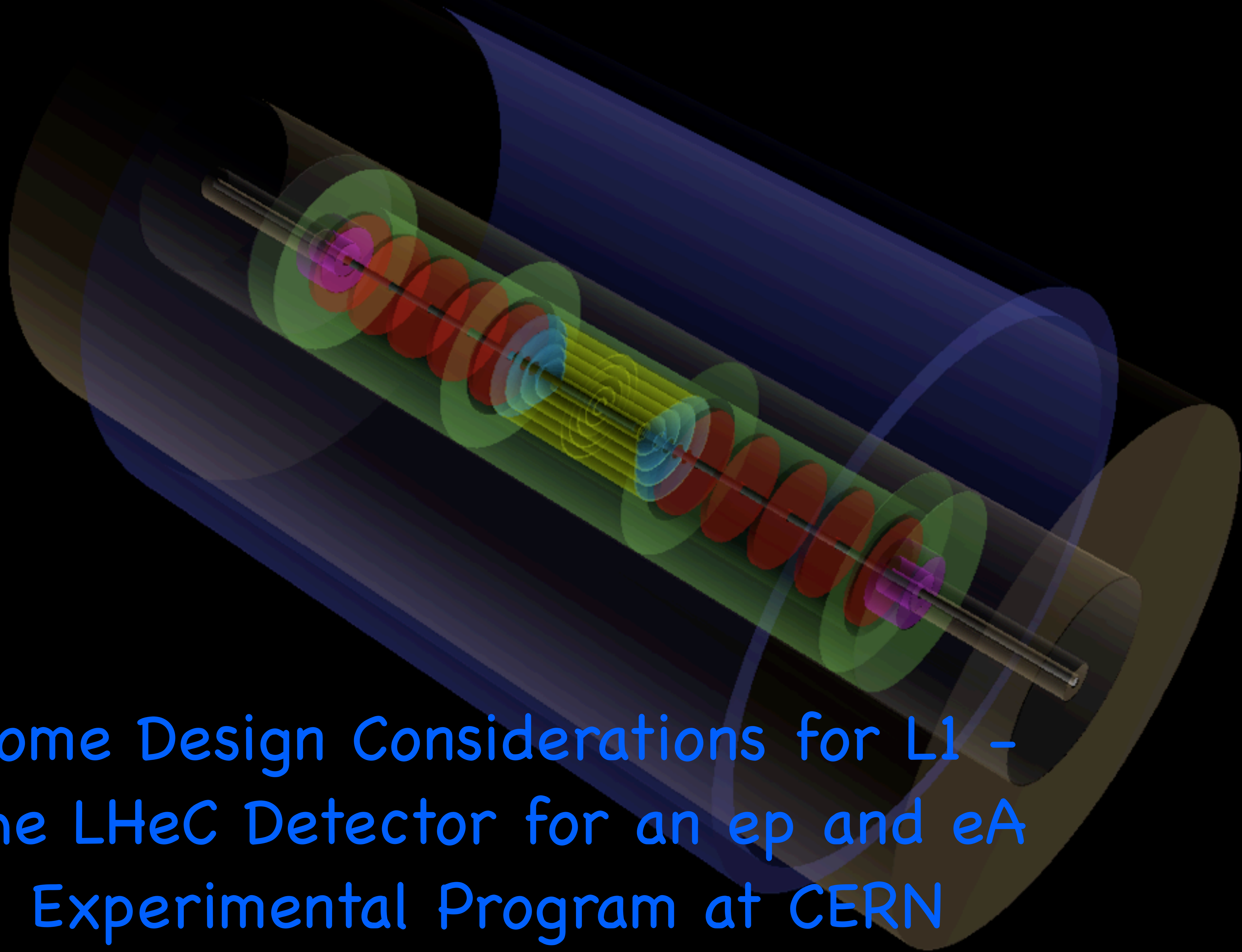
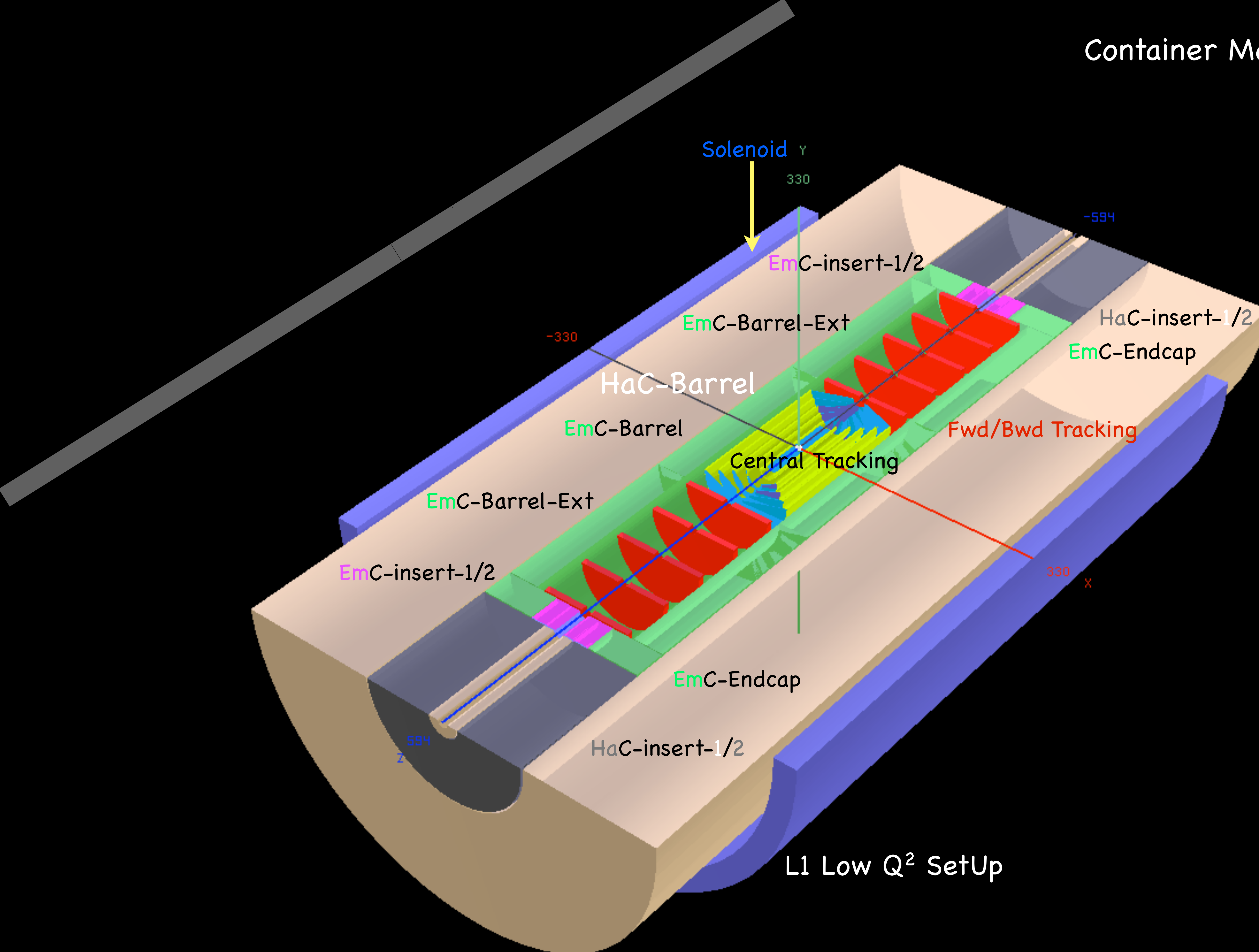


Some Design Considerations for L1 – the LHeC Detector for an ep and eA Experimental Program at CERN

Container Model



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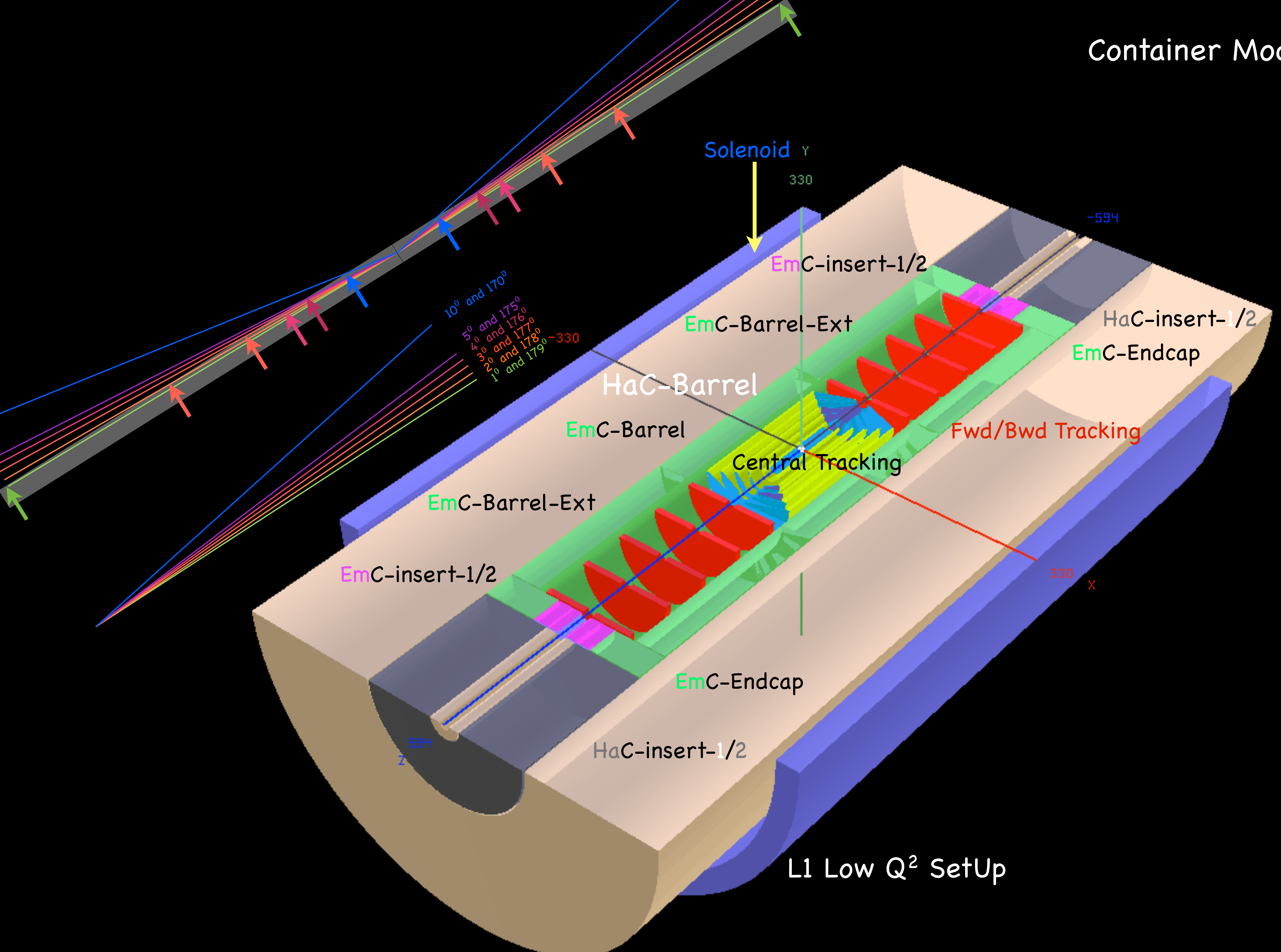

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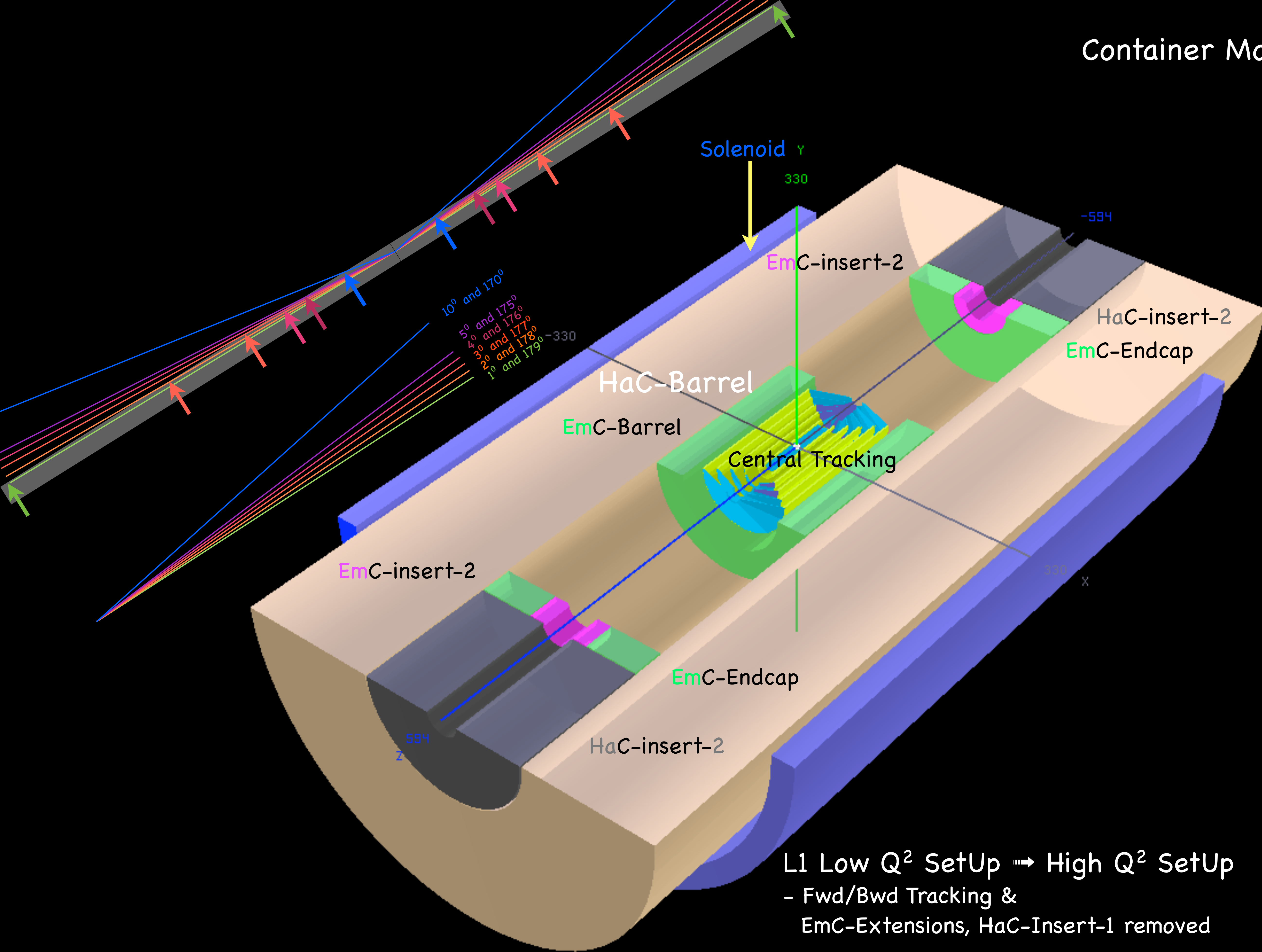
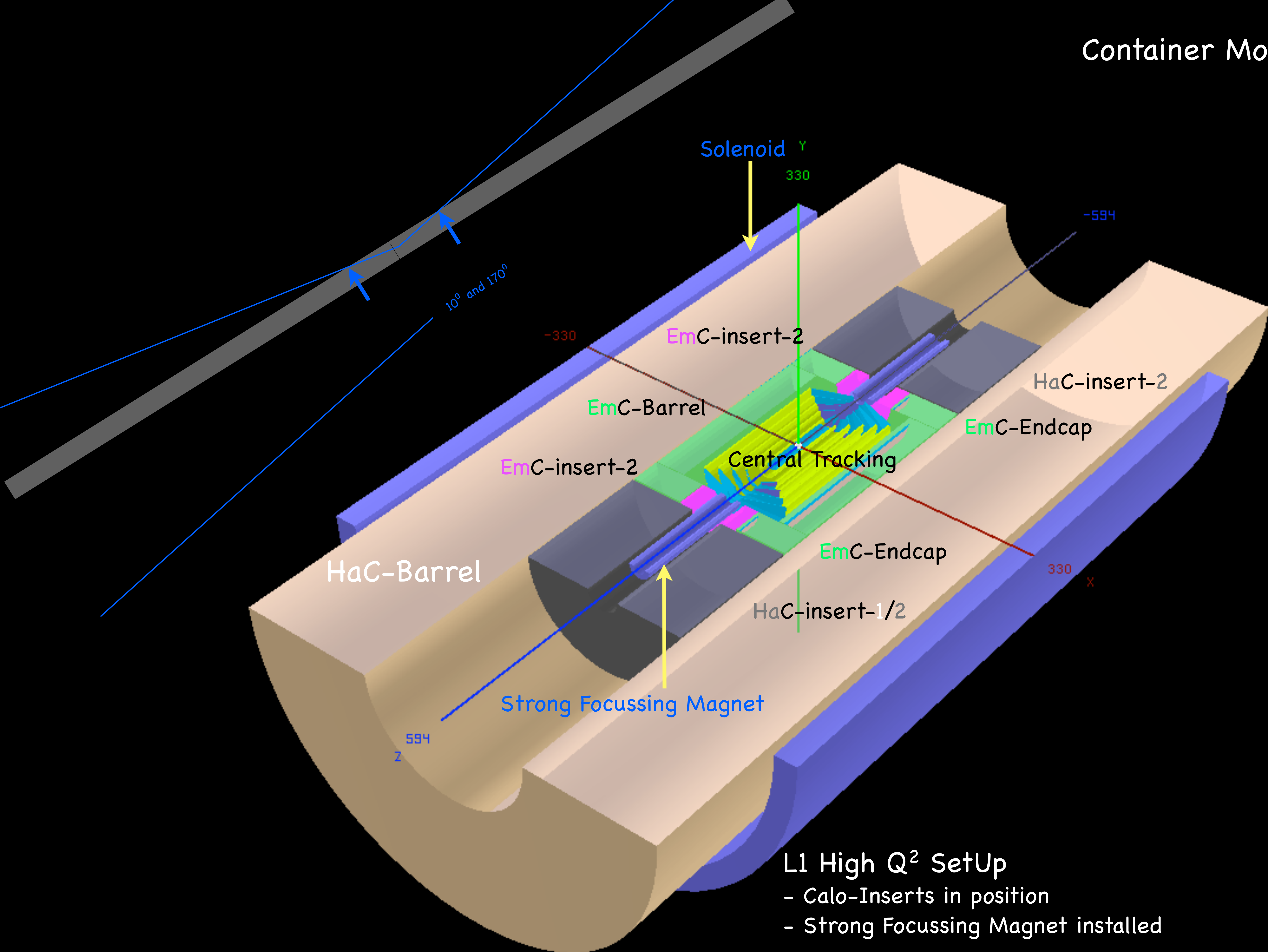


L1 Low Q^2 SetUp ➟ High Q^2 SetUp

- Fwd/Bwd Tracking & EmC-Extensions, HaC-Insert-1 removed

Container Model

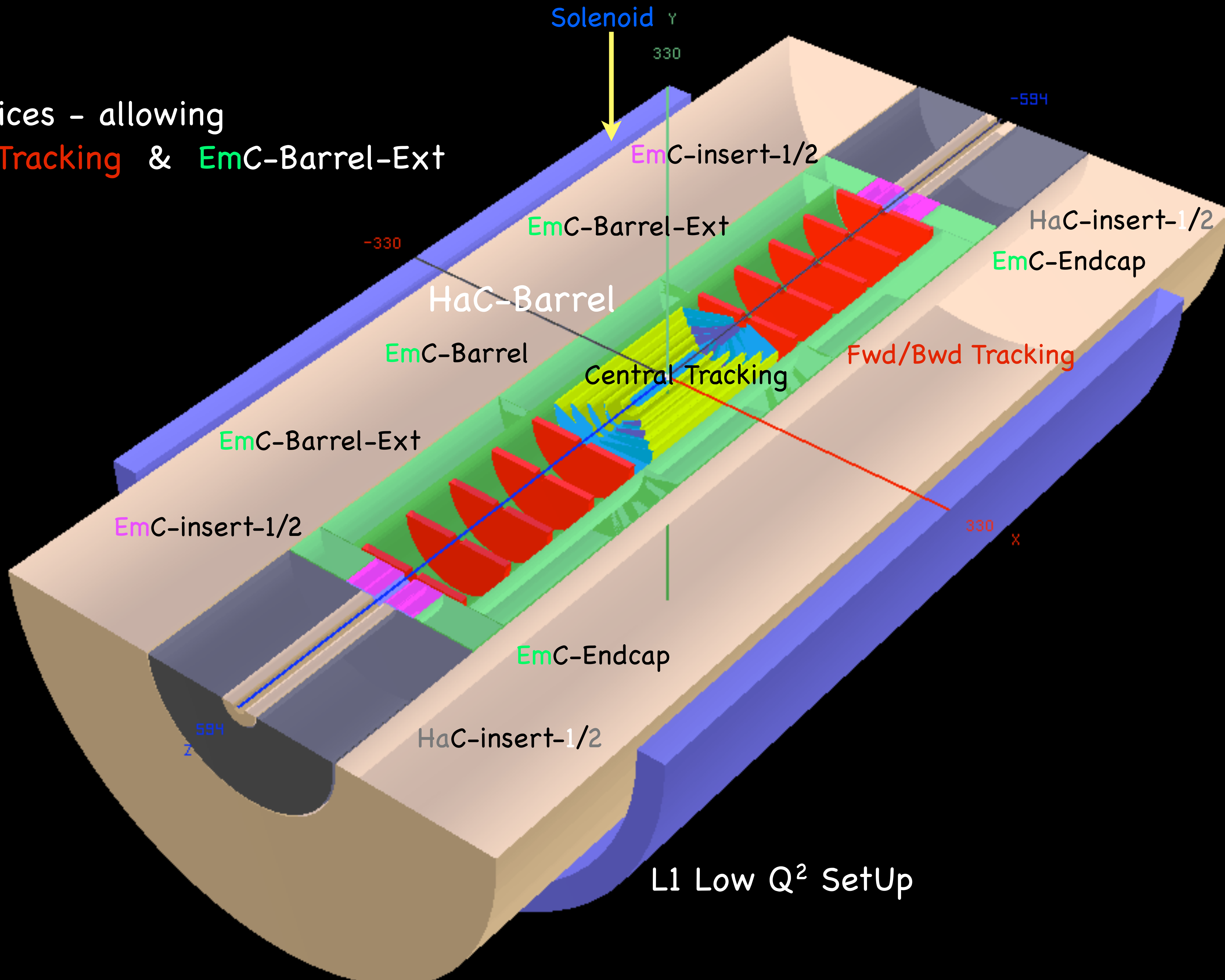


L1 High Q^2 SetUp

- Calo-Inserts in position
- Strong Focussing Magnet installed

Container Model

Routing of Services - allowing
Fwd/Bwd Tracking & EmC-Barrel-Ext
removal



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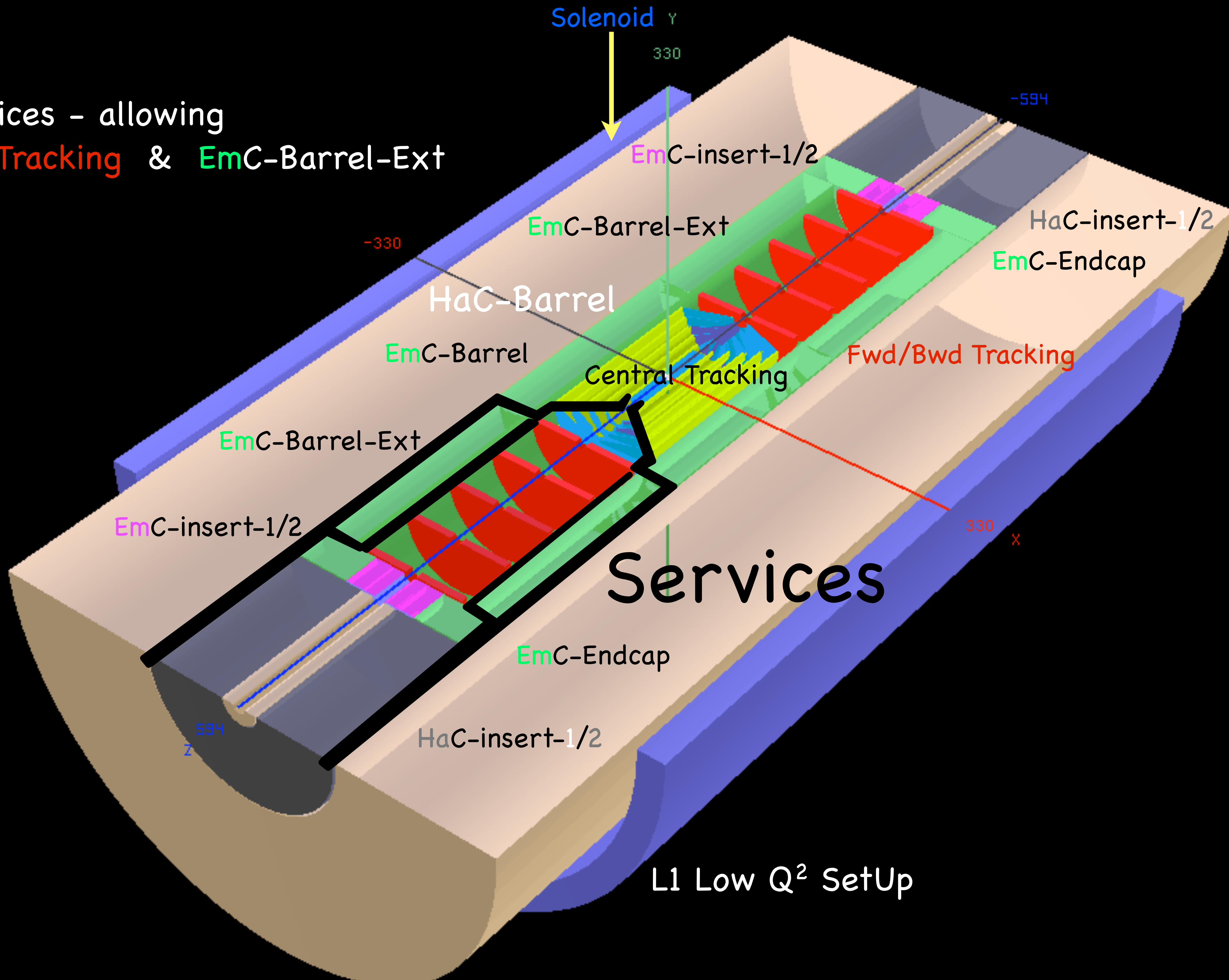
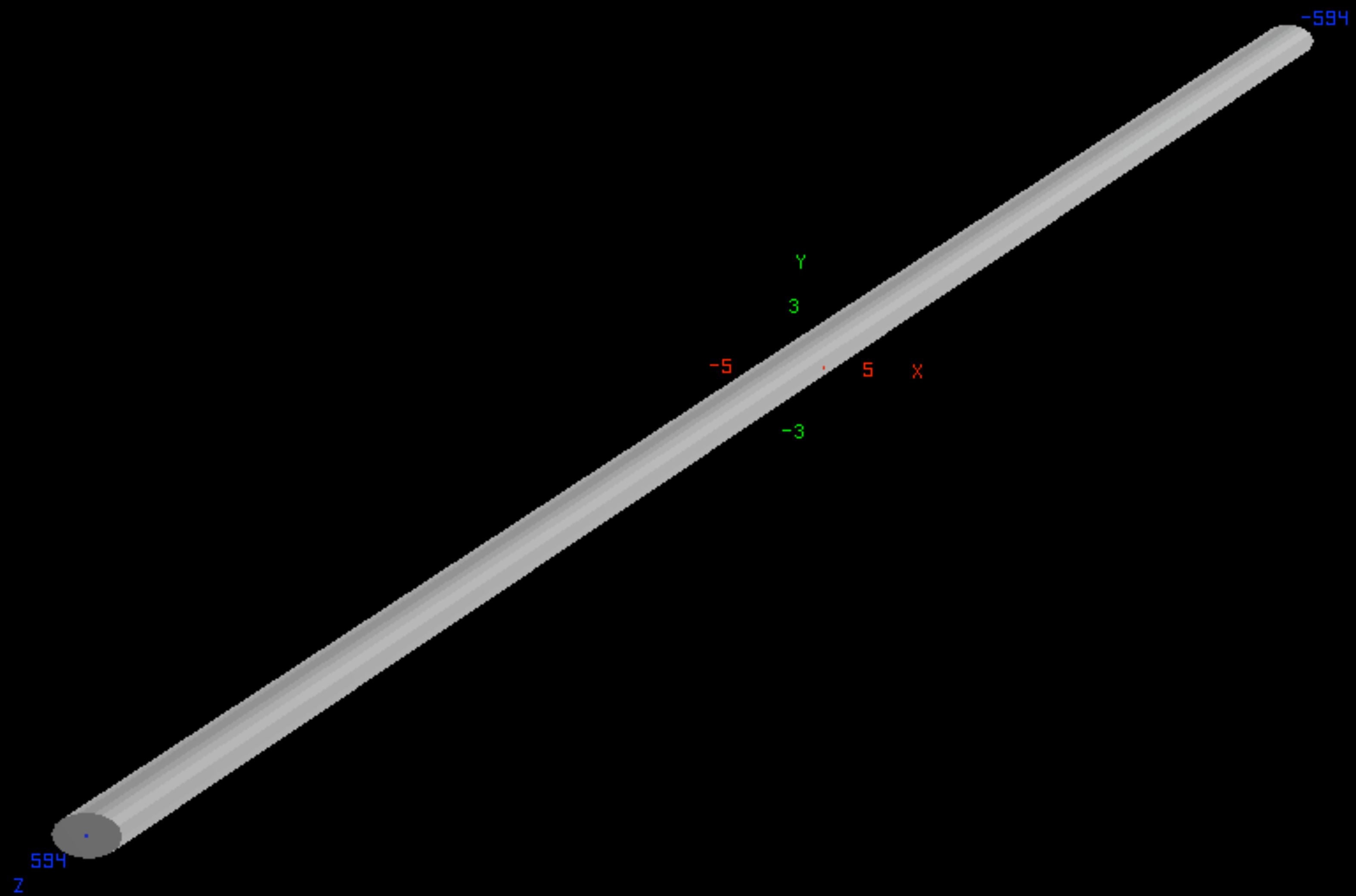


L1 Low Q^2 SetUp

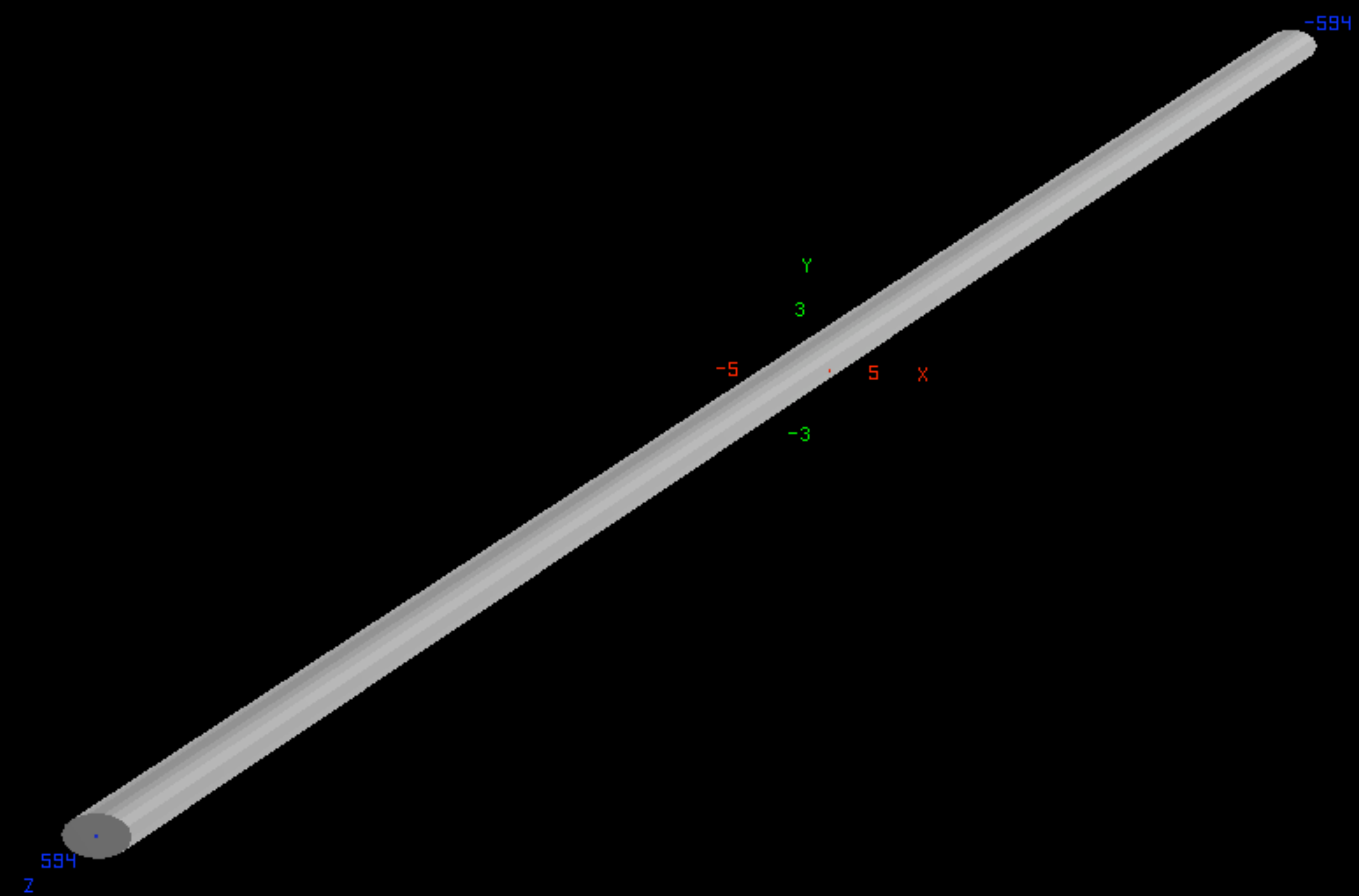
Beam Pipe



Beam Pipe

- Elliptical Be beam pipe radii:

  r_y=3.4cm and r_x=5.4cm – Sufficient space for synchrotron radiation fan?



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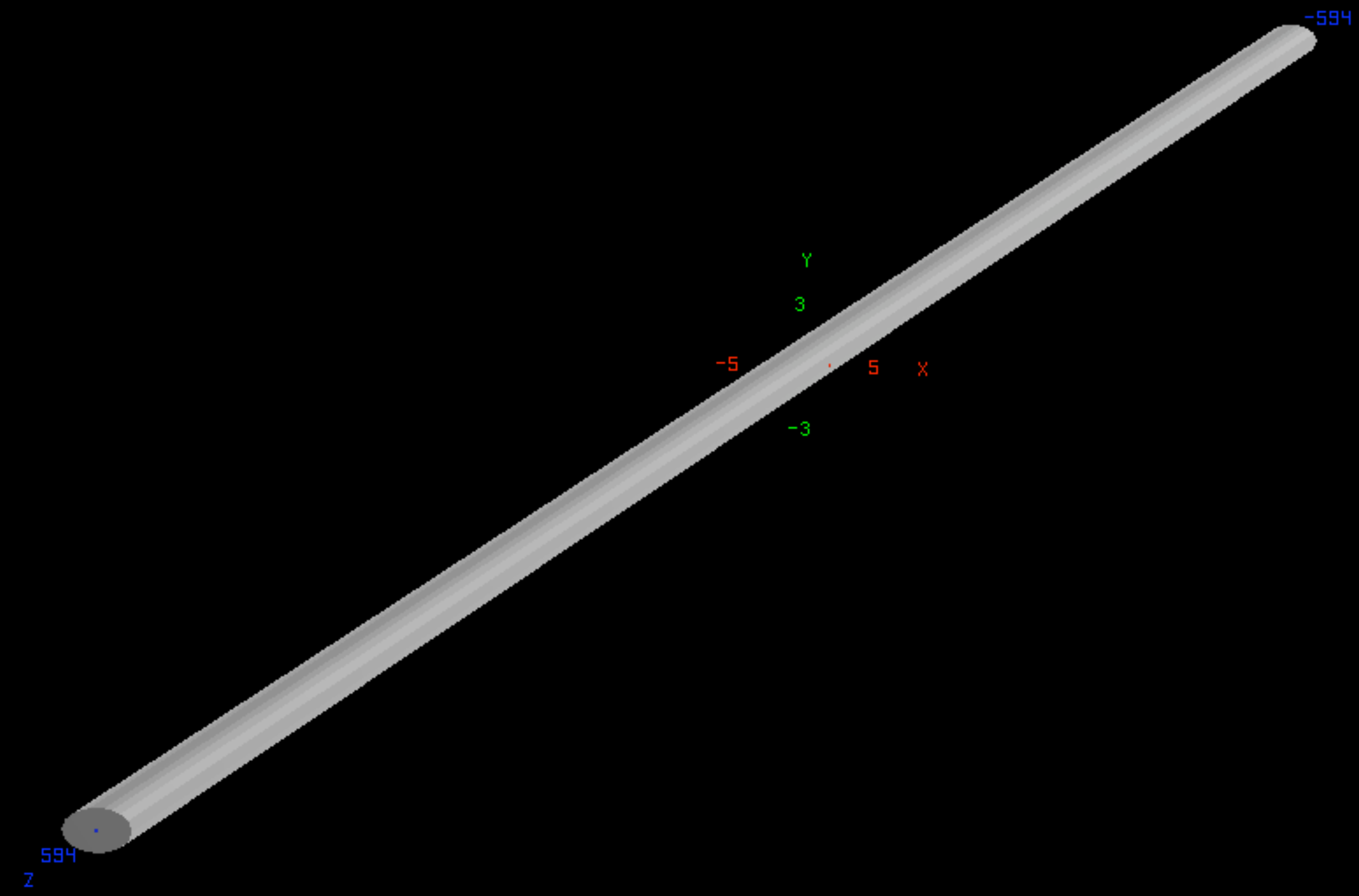

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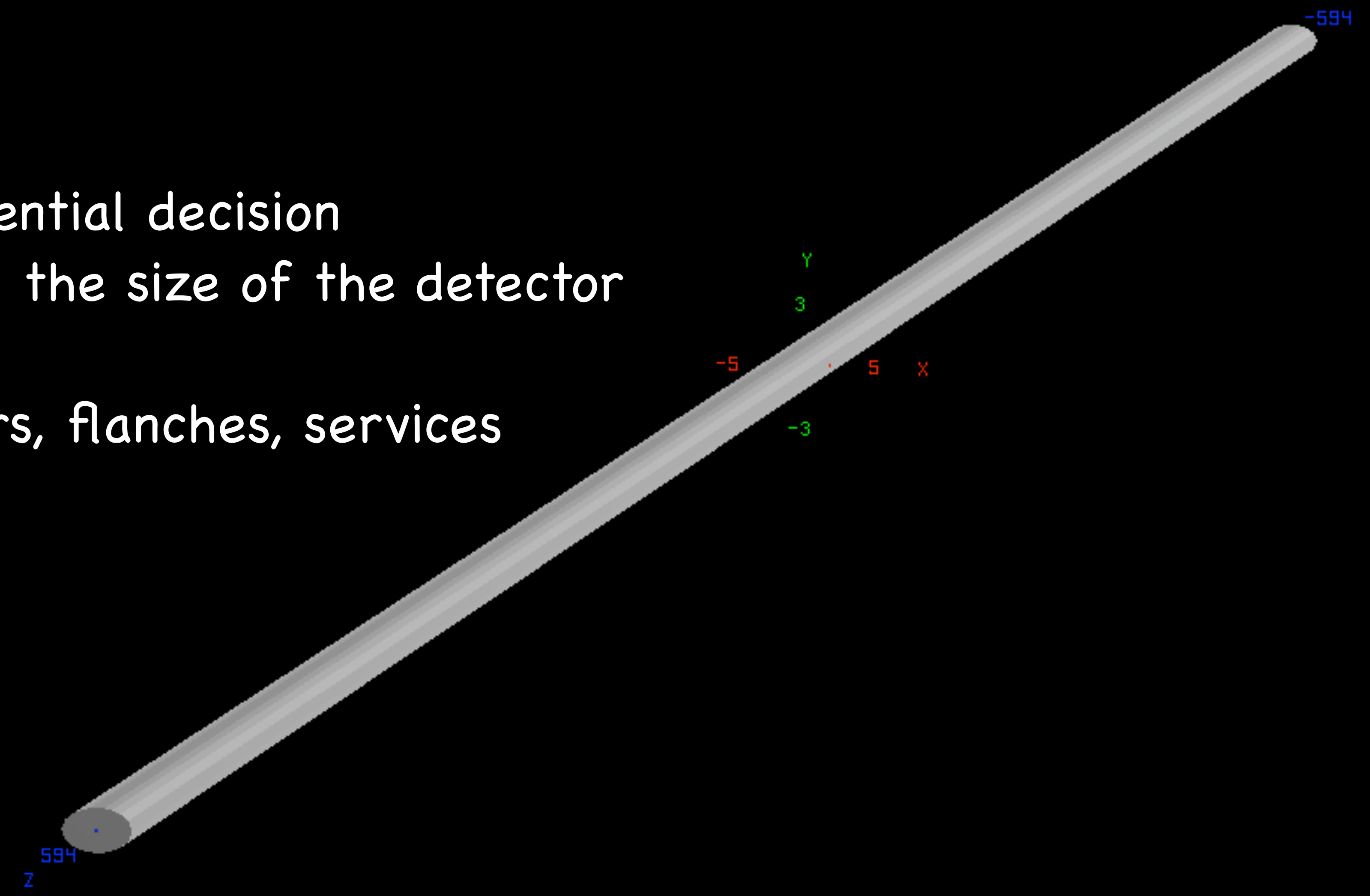
- X_0 = 35cm, Z = 4

- pipe dimensions - very essential decision
  to large extent determines the size of the detector

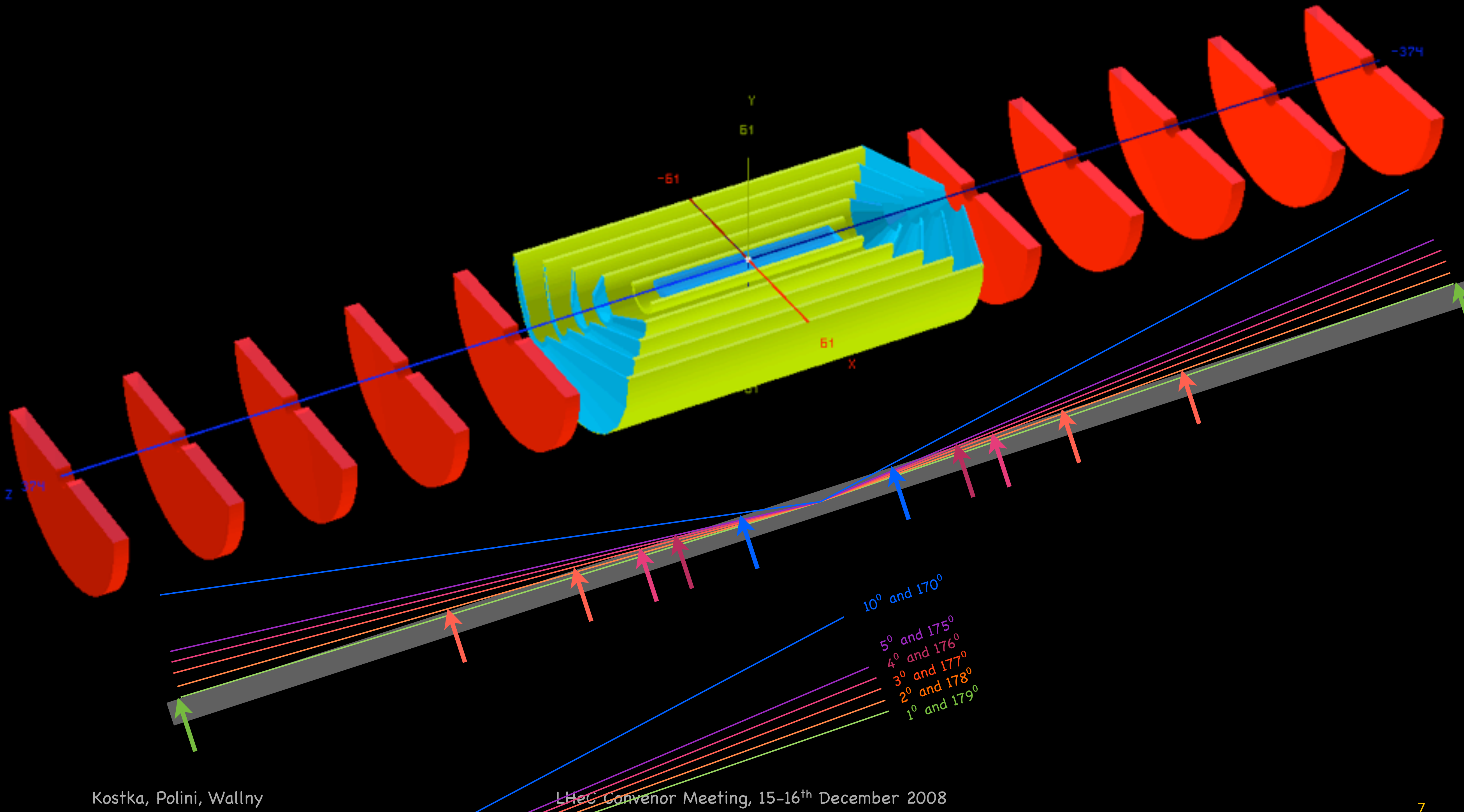
  not yet included: collimators, flanches, services



Near Beam Pipe Tracking

GAS-Si Tracker - GOSSIP Type ©NIKHEF

Gas On Slimmed Silicon Pixels (or Strixels/Pads)



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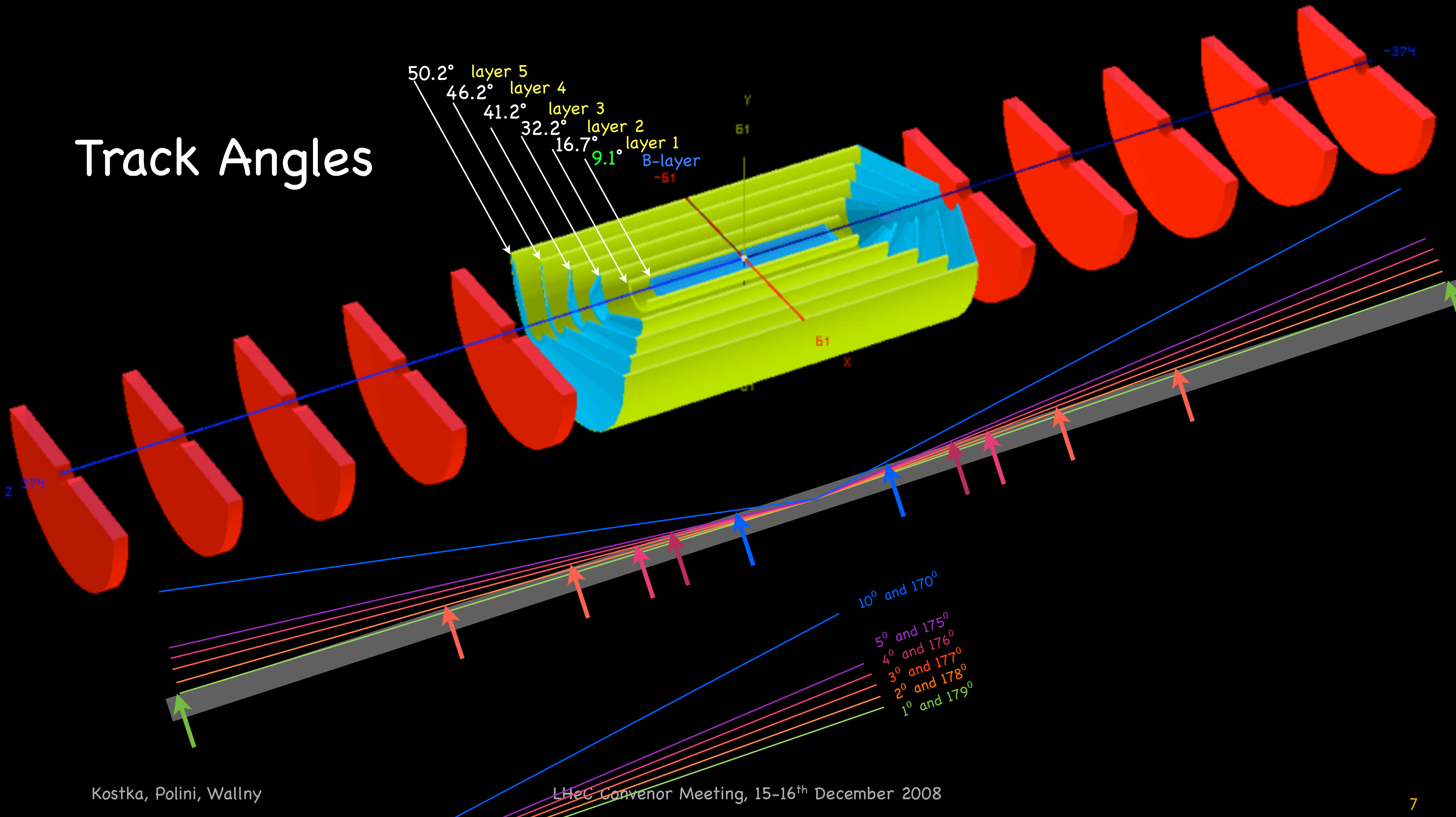
Gas On Slimmed Silicon Pixels (or Strixels/Pads)

Track Angles



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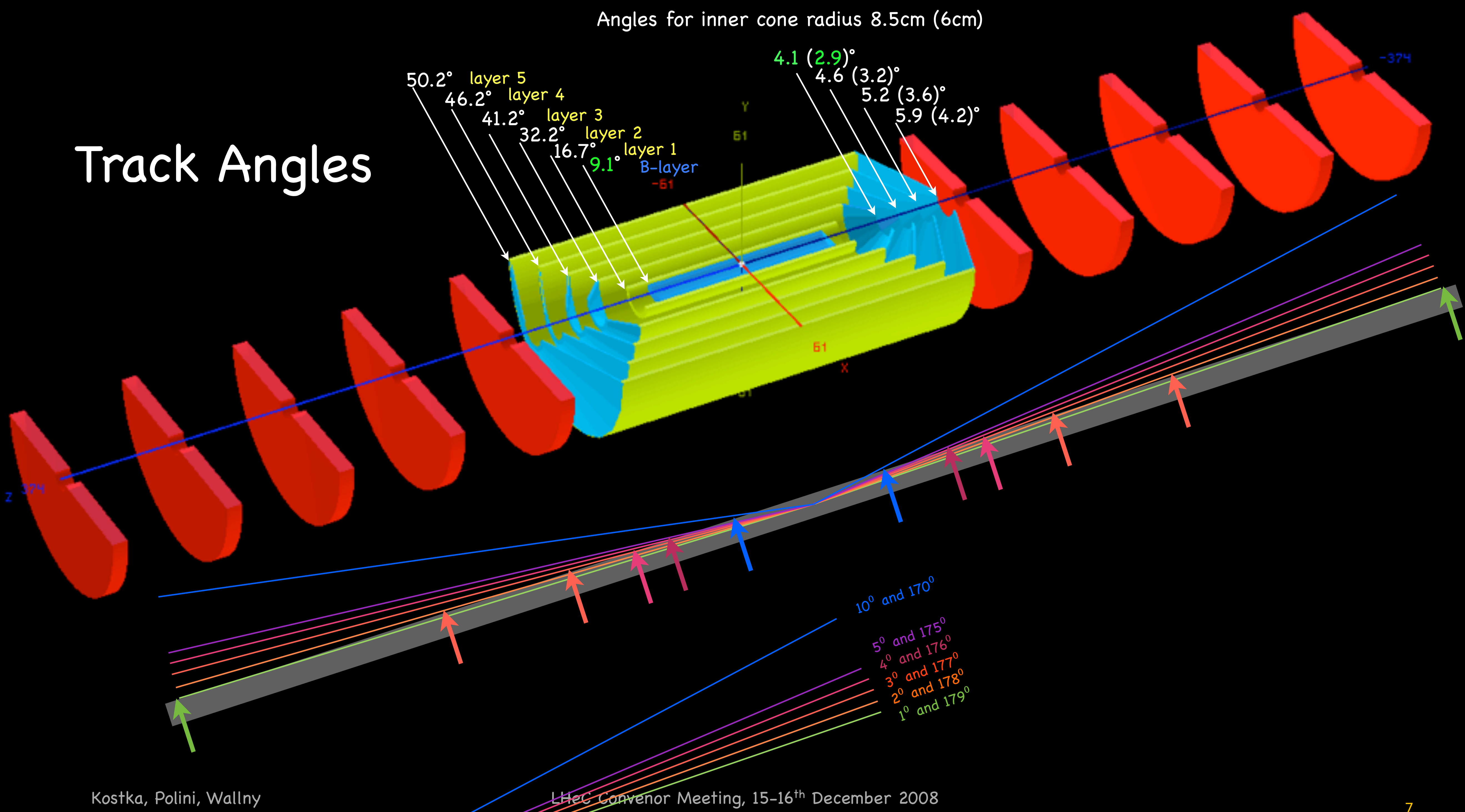

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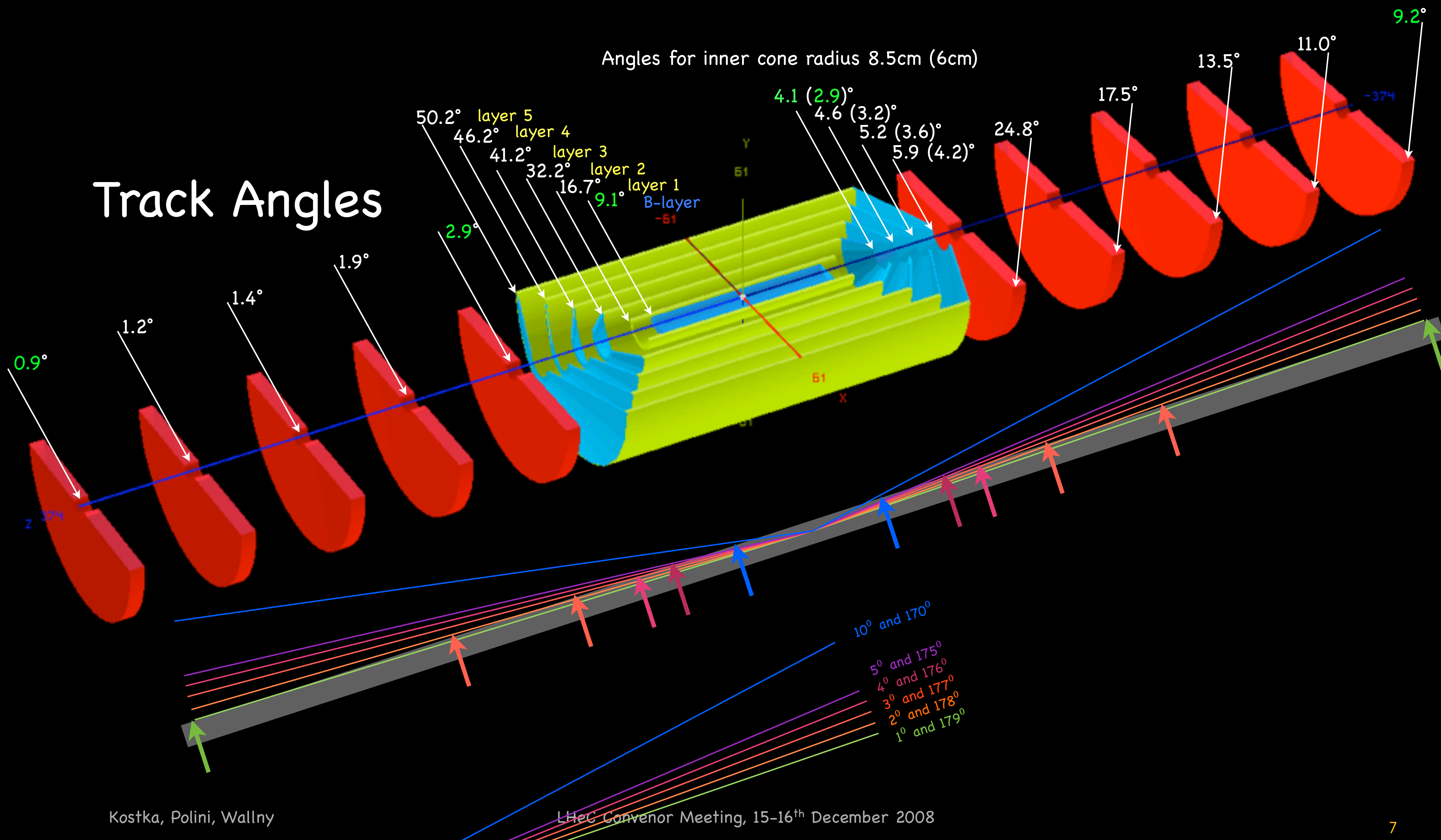

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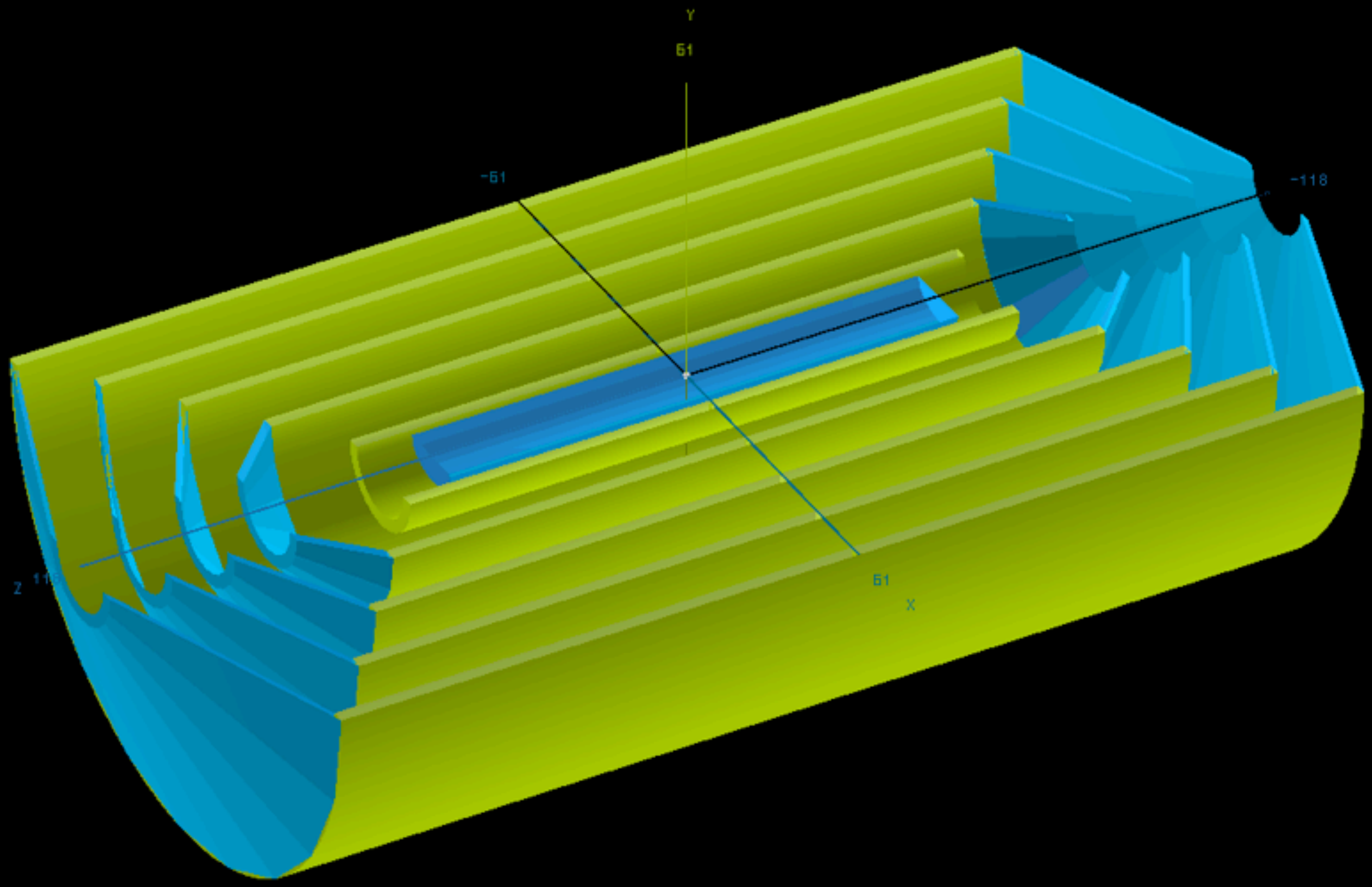

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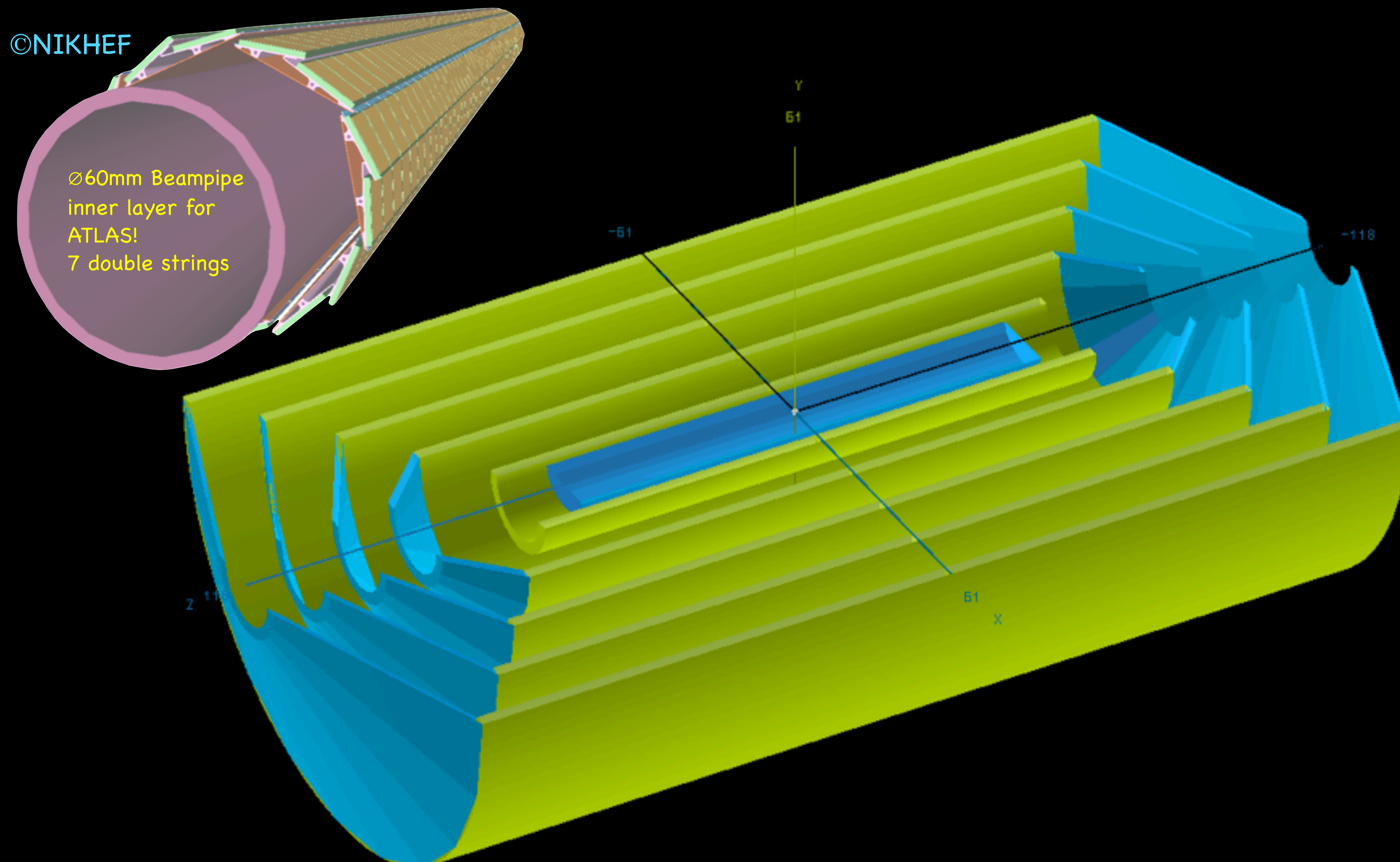

L1 elliptical beam pipe radii:
r_y=3.4cm and r_x=5.4cm

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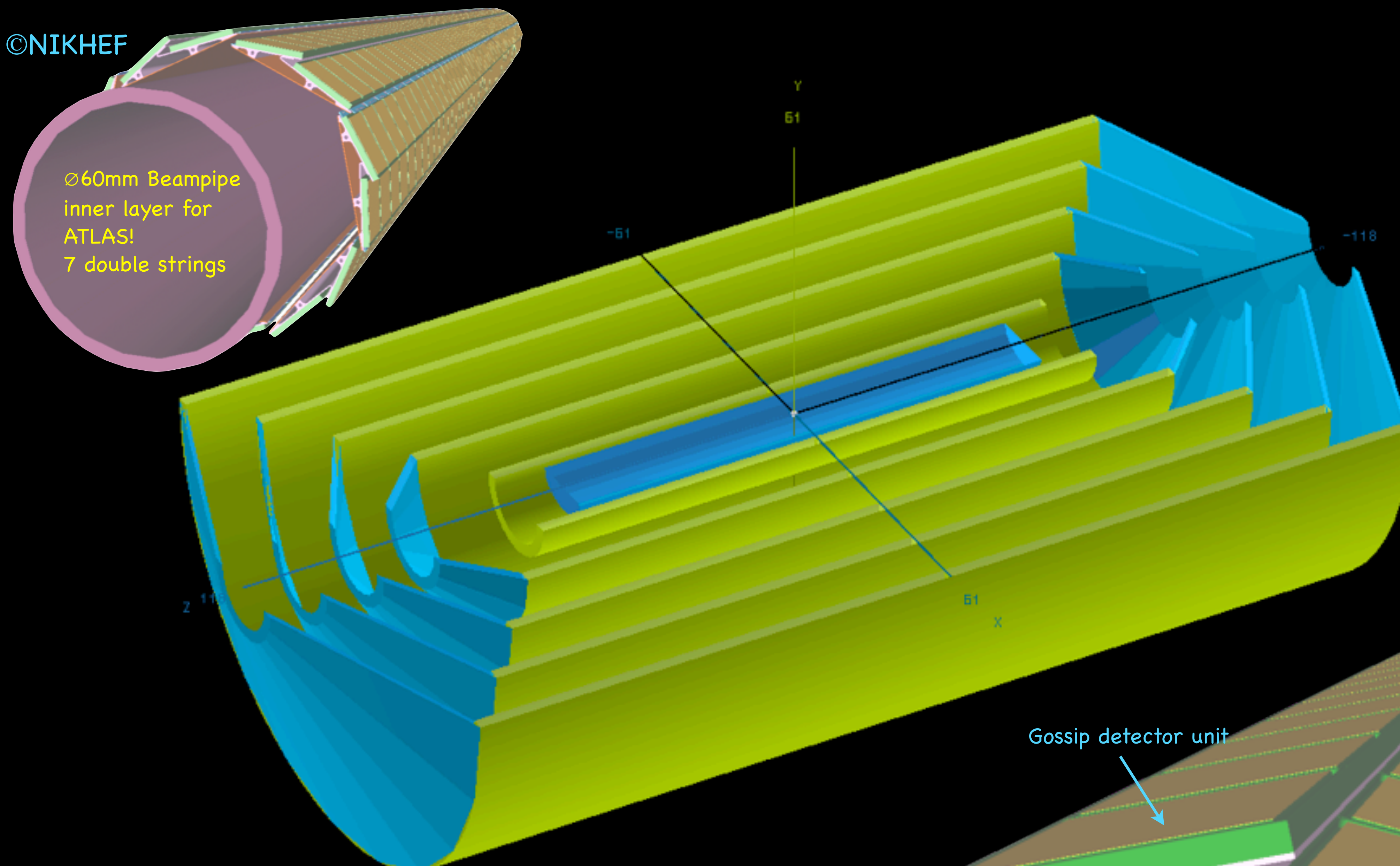

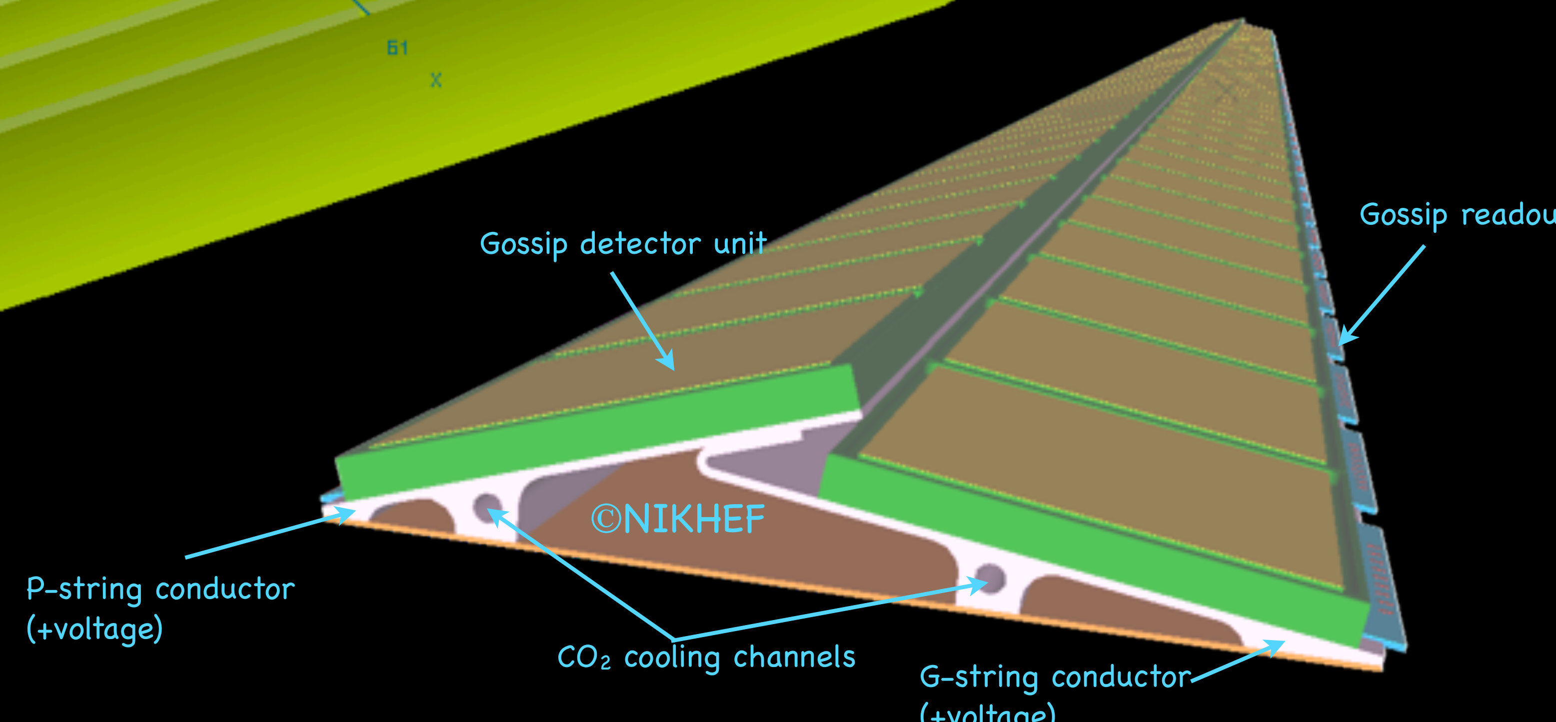

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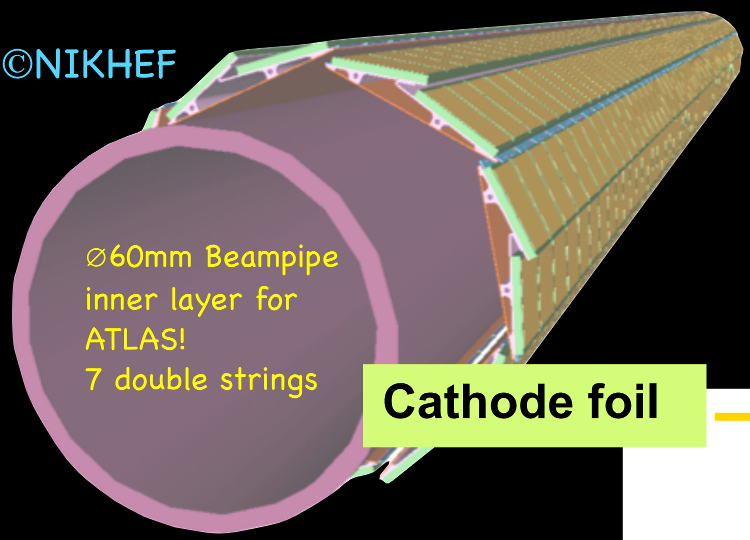

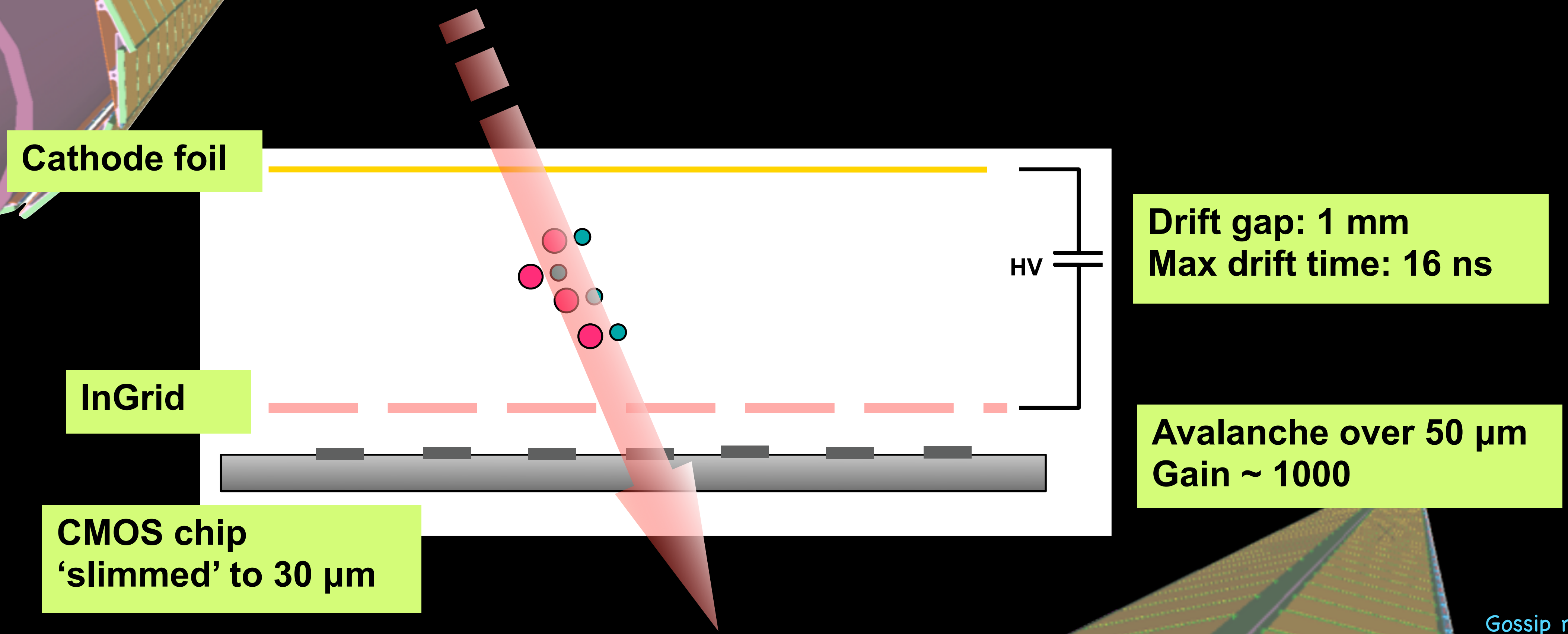

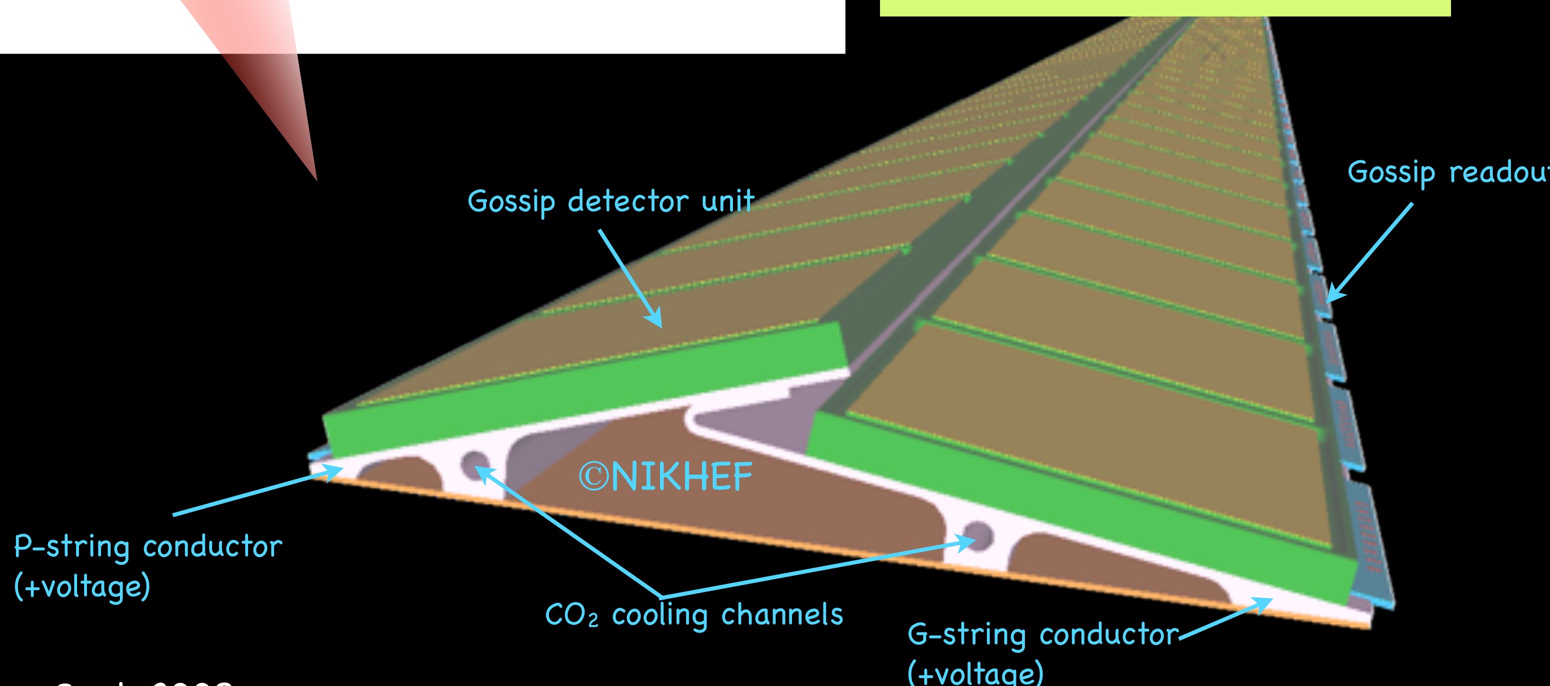

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Gas in a tracking detector

- Amplification of primary electrons in gas
  - No bias current
  - Low capacitance (10 fF) per pixel
- No radiation damage of sensor
  - Operation at room (or any other) temperature
- low sensitivity for neutron and X-ray background
- δ-rays can be recognized
- High ion & electron mobility: fast signals, high count rates are possible

This may result in a design with:

1. Less power consumption
2. Less cooling
3. Reduced complexity (wafer processing instead of bumping)
4. Less material

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Plans

- Large drift volume :TPC for a linear collider
- Micro TPC for nuclear physics
- Thin drift layer : B-layer for ATLAS
- Radiator : transition radiation tracker
- High field : micro channel plate

- LHeC ?

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↳ **Collaboration for an advanced LHeC Detector!**

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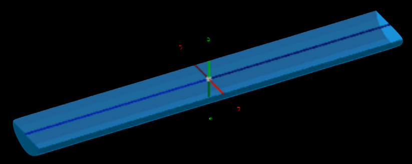
Tracker Details 1

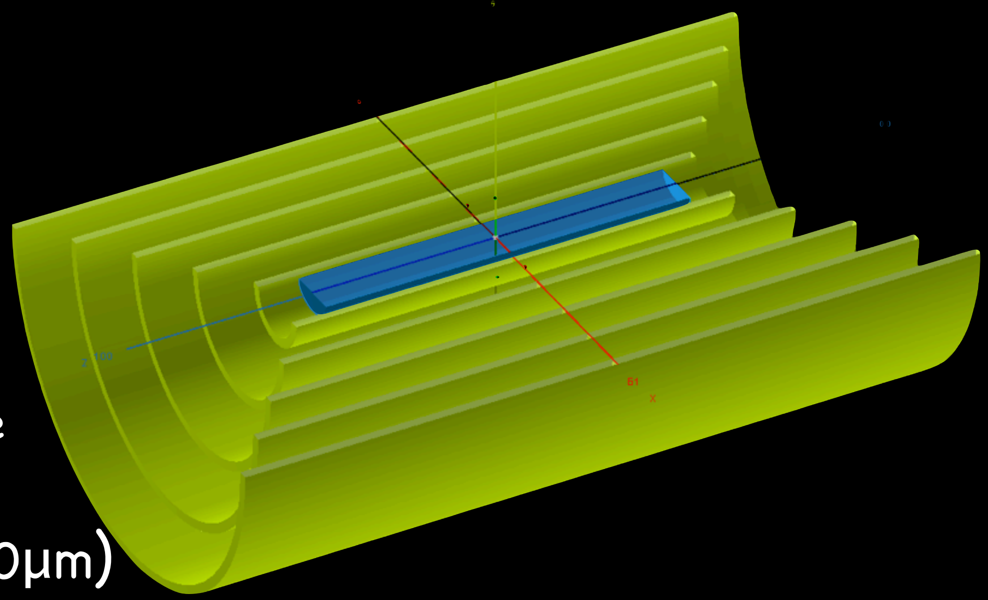


- Central Tracker
  - B - Double Layer Pixel elliptical(?)
    r_y=5.2cm and r_x=7.2cm (outer radii), 50cm length - trigger capable

    - highest resolution affordable (i.e. pixel 20μm x 20μm)
      gas-si: using fast & low_diffusion & safe gas mixture

Tracker Details 1

- Central Tracker



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- 5 cylindrical barrel Gas-Si tracker (double) layers*

layer #	inner radius	outer radius	half length - all [cm]
1	8.5	11.0	30.0
2	21.0	23.5	35.0
3	33.5	36.0	40.0
4	46.0	48.5	45.0
5	58.5	61.0	50.0

* b-quark triggering (secondary vertex) to be implemented

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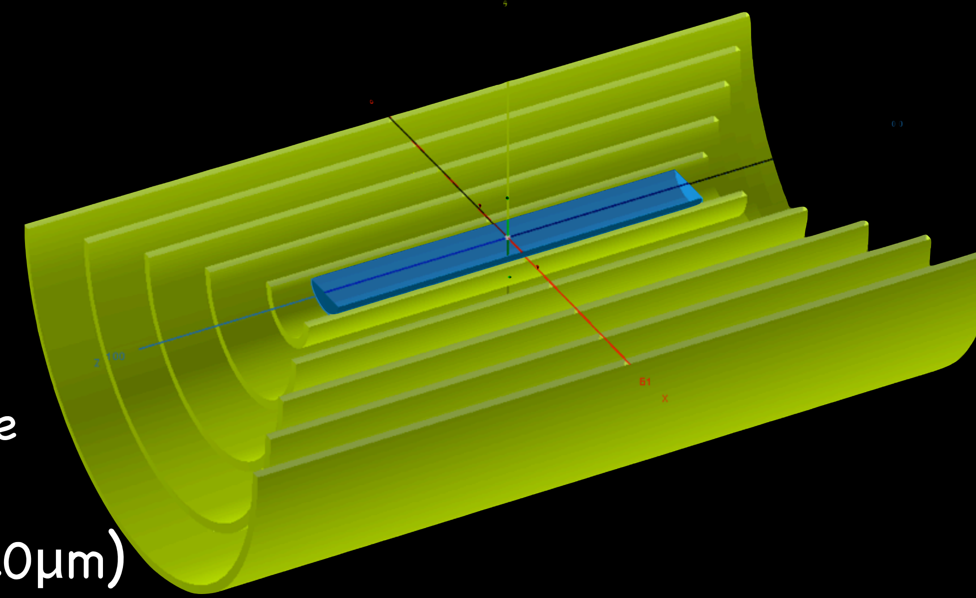

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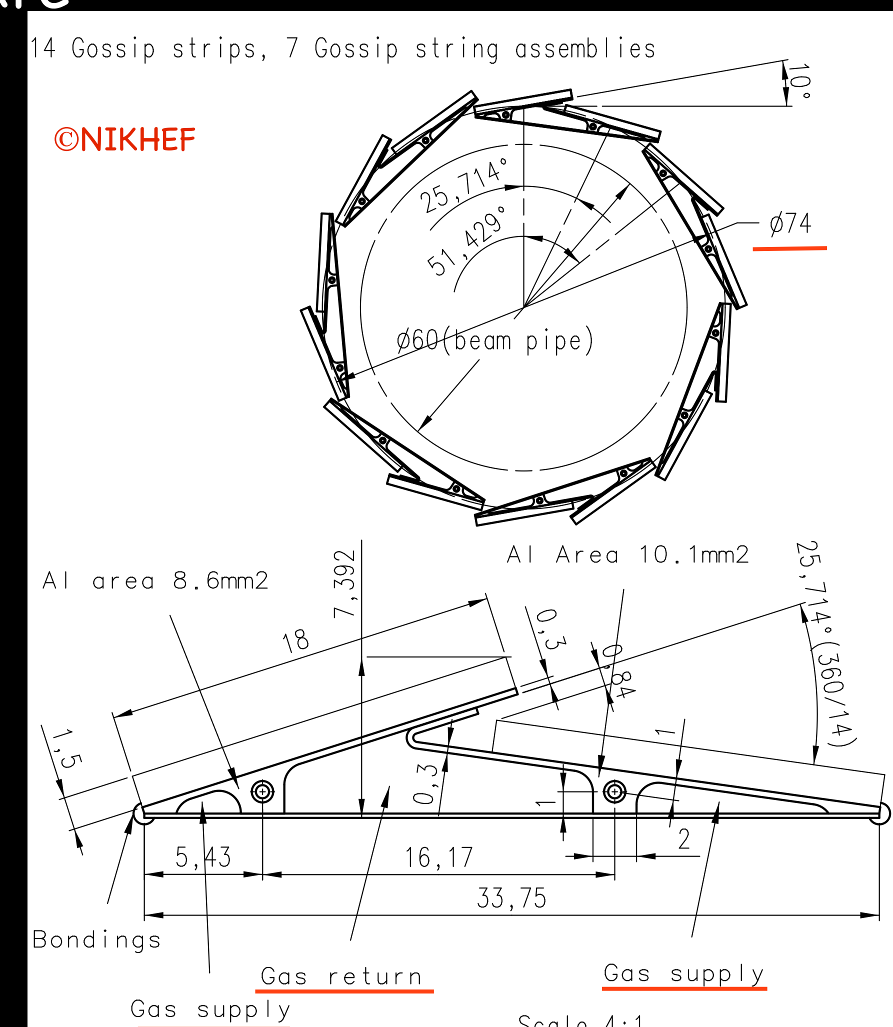

Tracker Details 2

- 2 x 4 cone shape forward/backward Gas-Si tracker (double) layers

cone #	Dz-half length in z	innerR at -Dz	outerR at -Dz	innerR at +Dz	outerR at +Dz	end_coordinates ±z	all [cm]
1 (lay2)	6.0	8.5	11.0	21.0	23.5	82.0	
2	7.0	8.5	11.0	33.5	36.0	94.0	
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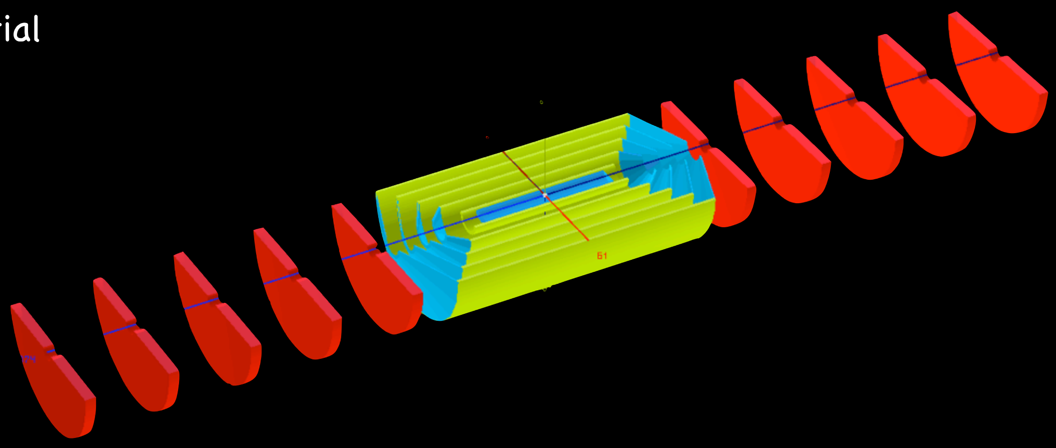
↑ could be 6cm - B-layer installation sequence essential



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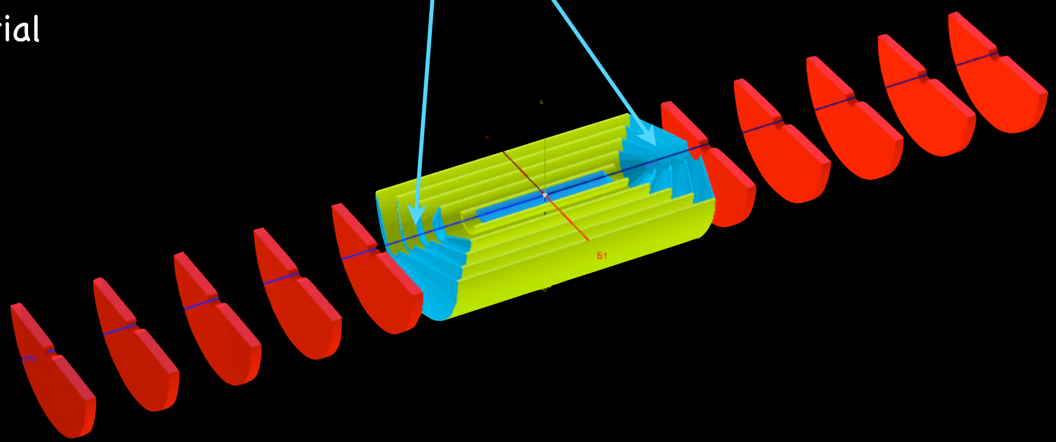

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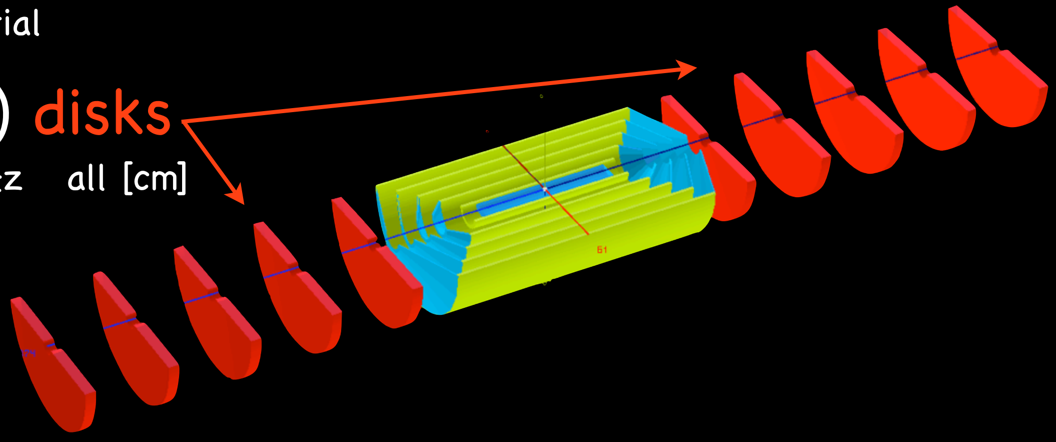

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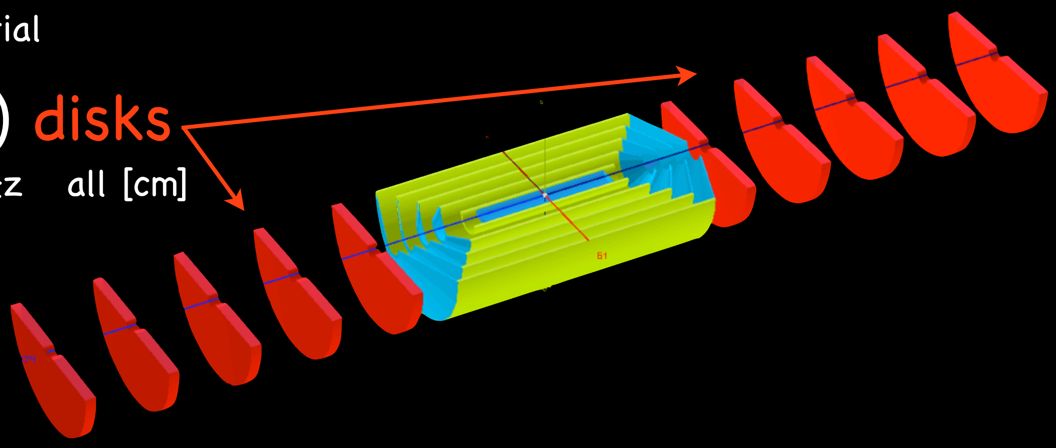

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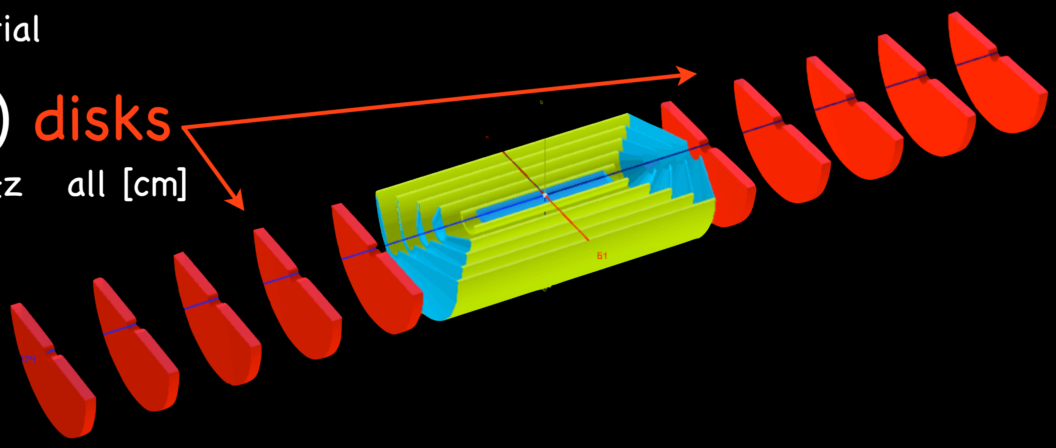

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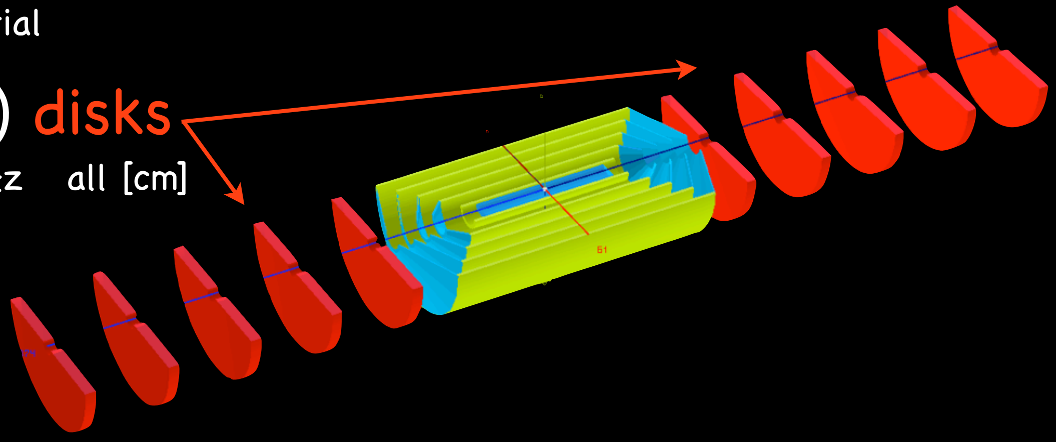

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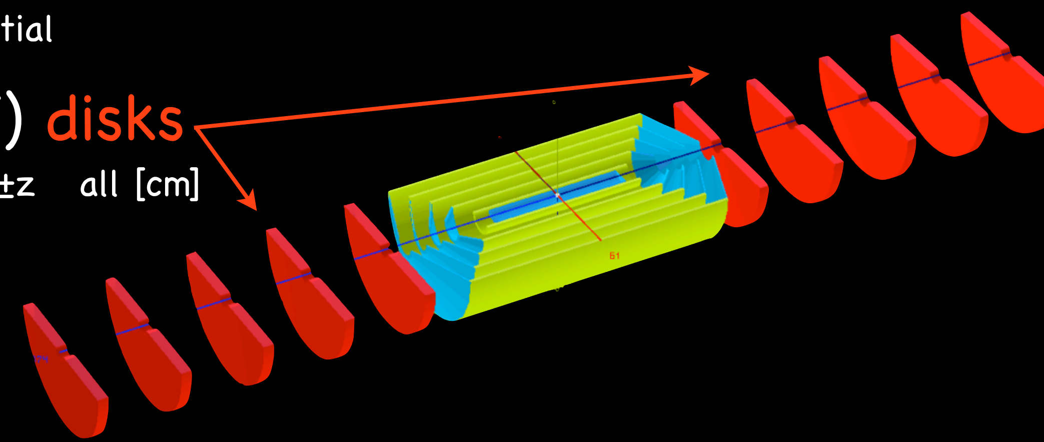

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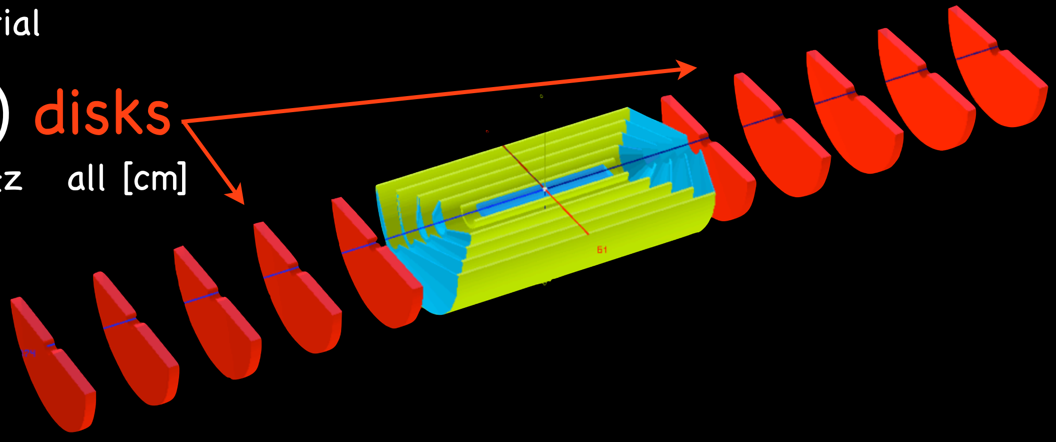

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  - low sensitivity for neutrons, X-rays and gammas
  - 1 mm gas detection layer: single-electron measurement -> track segment data per layer

Tracker Details 2

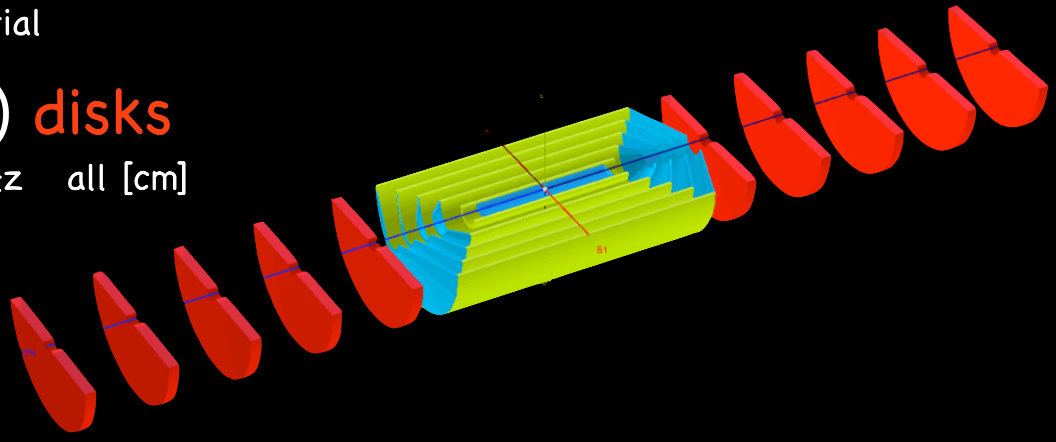
- 2 x 4 cone shape forward/backward Gas-Si tracker (double) layers

cone #	Dz-half length in z	innerR at -Dz	outerR at -Dz	innerR at +Dz	outerR at +Dz	end_coordinates ±z	all [cm]
1 (lay2)	6.0	8.5	11.0	21.0	23.5	82.0	
2	7.0	8.5	11.0	33.5	36.0	94.0	
3	8.0	8.5	11.0	46.0	48.5	106.0	
4	9.0	8.5	11.0	58.5	61.0	118.0	

↑ could be 6cm - B-layer installation sequence essential

- 2 x 5 forward/backward Gas-Si tracker (2/4*) disks

disk #	inner radius	outer radius	half length	end_position ±z	all [cm]
1	6.0	60.0	4.0	134.	
2	6.0	60.0	4.0	194.	
3	6.0	60.0	4.0	254.	
4	6.0	60.0	4.0	314.	
5	6.0	60.0	4.0	374.	



*it might be necessary to have sandwiches of double disk's for track triggering + double disk's for tracking

- Some characteristics:
  - thinning (slimming) of CMOS pixel/strixel/pad chip to 50 µm
  - low power: 2.6 µW/pixel -> 1-4 mW/cm^2 (pixel-strixel): little material required for power & cooling (CO_2 gas)
  - low sensitivity for neutrons, X-rays and gammas
  - 1 mm gas detection layer: single-electron measurement -> track segment data per layer
  - Mechanical concept: integration of services (cooling, power, communication), detectors and support structure (see BackUp slides)

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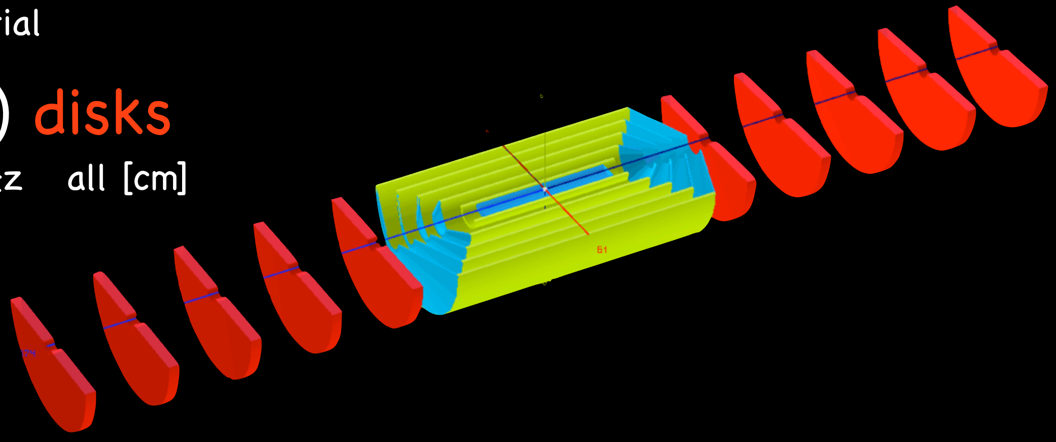

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Radiation Length [%]

		Z = 0 mm		Z = +/-500 mm
Gossip detector (50 µm Si)		0.06		0.06
Cooling (stainless steel tube)		0.001		0.001
Power (max 0.28 mm aluminium)		0.0		0.3
Data transfer (max 1.7 mm kapton)		0.0		0.6
total		0.06		1
max number of track layers (#)		0.72 (12)		30 (30)
angle correction	x √2	0.09	x 2 x √2	3

Energy Flow Calorimetry*

* see talk of F.Simon: CALICE - Calorimeters for the ILC, LHeC workshop, Divonne Sept. 2008

Energy Flow Calorimetry*

- EmCaL E-flow Optimisation

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Energy Resolution

$E_{jet} = E_{charged\_particles} + E_{photons} + E_{neutral\_hadrons}$

~60%	~30%	~10%
TRACKERS	ECAL	HCAL

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Energy Flow Calorimetry 2

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Energy Flow Calorimetry 2

- A dense EmCAL with high granularity (small transverse size cells), high segmentation (many thin absorber layers), and with ratio λ_I/X_0 large, is optimal for E-Flow measurement -> 3-D shower reconstruction

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- Example Fe, W

Material	Nuclear interaction length λ [cm]	Density $[g/cm^3]$	Moliere radius [cm]	Radiation length X_0 [cm]	λ/X_0
Fe	16.98	7.87	1.66	1.77	9.59
W	10.31	19.3	0.92	0.35	29.46

- brass (Cu) an option also (CMS), λ_I =15.1cm - denser than Fe (adding λ_I)

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CALICE: Technology

- All calorimeters designed for Particle Flow
  - high granularity: unprecedented longitudinal and transverse segmentation
- Compact devices to accommodate large channel count
  - integrated electronics on detector where possible:
    - ASICs mounted on active material
    - photon sensors directly on scintillator tiles
- Investigation of different technologies:
  - silicon vs scintillators
  - scintillators vs gaseous detectors
  - analog vs digital

CALICE Hardware: Outlook

- Proof of Concept of highly granular calorimeters with present setup
- Comparison of technologies:
  - Si-W vs Scint-W ECAL
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- Next steps:
- Development of next-generation prototypes within the EUDET framework:
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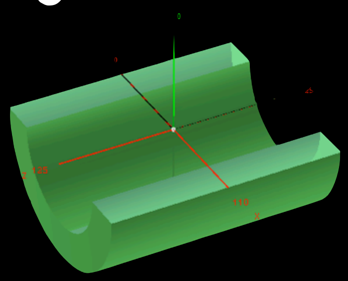
↳ **Collaboration for an advanced LHeC Detector!**

Calorimeter Details 1

- Electromagnetic Calorimeters - all 20 X_0

	inner radius	outer radius	half length	end Position ±z
EmC-Barrel	70.0	110.0	125.0	125.0



- EmC-Barrel,
  - Pb-fibre sandwich - 20 X_0 - R/O by position sensitive SiPM's
  - position resolution (H1 SPACAL type): 4.4mm/√(E[GeV] + 1.0mm), $\sigma(E)/E = 7\%/\sqrt{(E)} \otimes 1\%$

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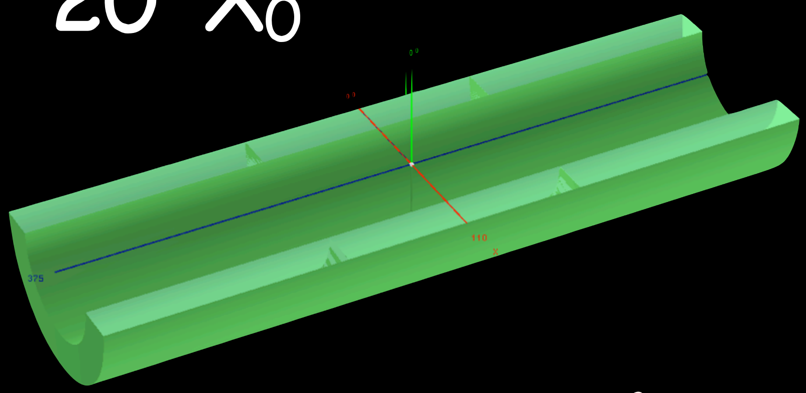

LowQ^2 EmC

- EmC-Barrel, EmC-Barrel-Extension for LowQ^2 (removable),
  - Pb-fibre sandwich - 20 X_0 - R/O by position sensitive SiPM's
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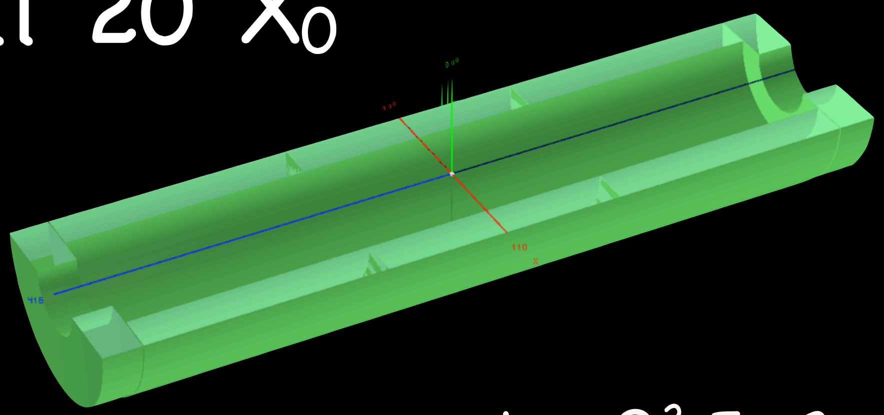

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    or Pb + si-gas Detector instead for higher position resolution (i.e. EmC-Endcap) - 11.2cm Pb + 28(sampling) x 1cm si-gas -> ~40cm
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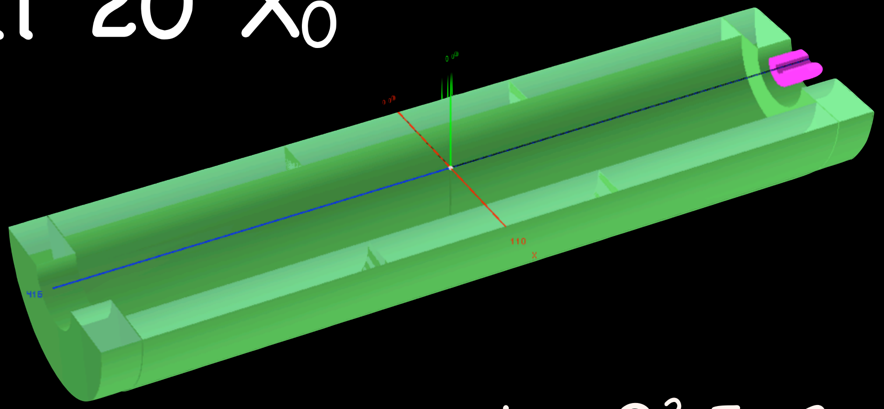

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- EmC-insert-1 Calice-type (removable),
  - tungsten X_0 by order of magnitudes smaller for oriented crystals (*)
  - tungsten + si-gas - 20 X_0 -> 7cm tungsten + 33(sampling) x 1cm plan. si-gas
    -> 40cm EmC-Endcap/EmC-inserts

* V.A.Baskov et.al., Pisma Zh. Eksp. Teor. Fiz. 56, No.5, 233-236 (September 1992)

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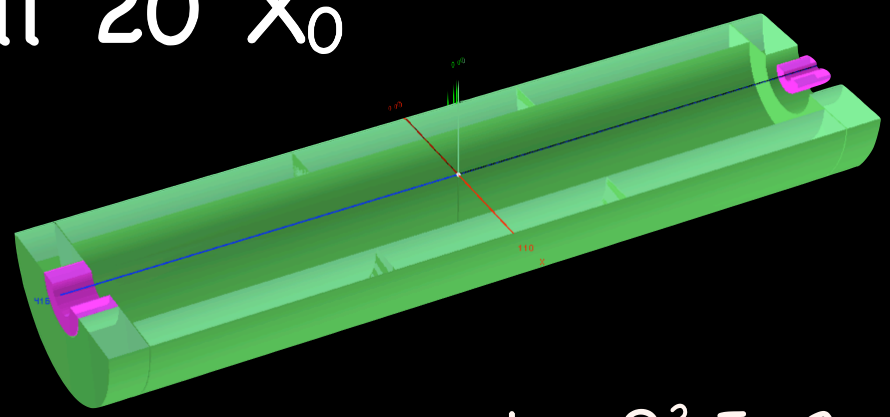

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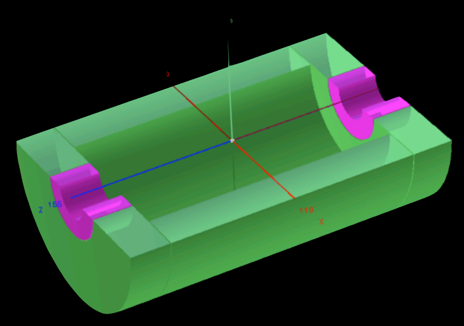

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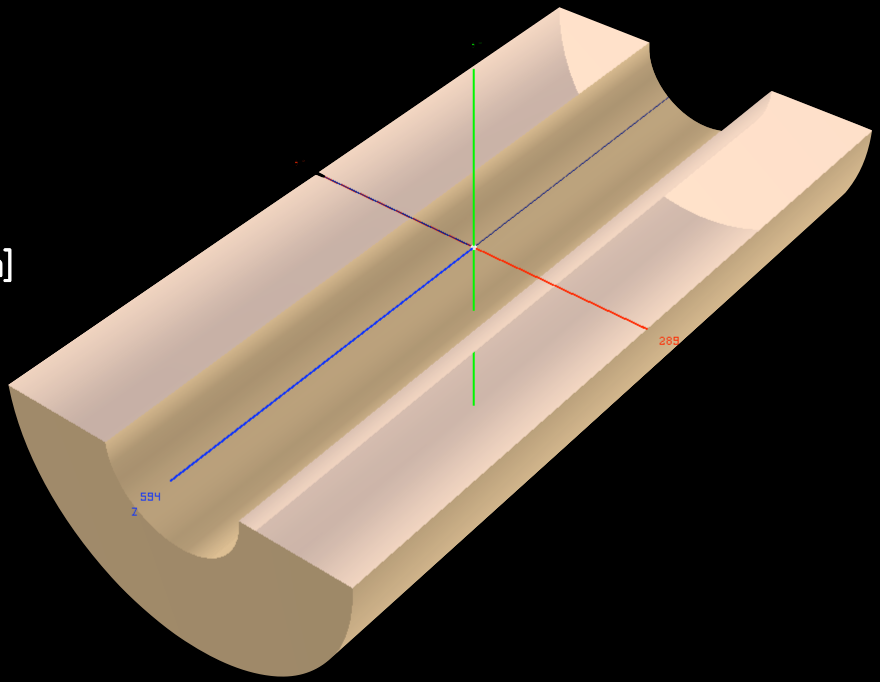


- Hadron Calorimeters - all 6 λ_I

	inner radius	outer radius	half length	end Position ±z (HighQ²) [cm]
HaC-Barrel	112	289	594	594

- HaC-Barrel

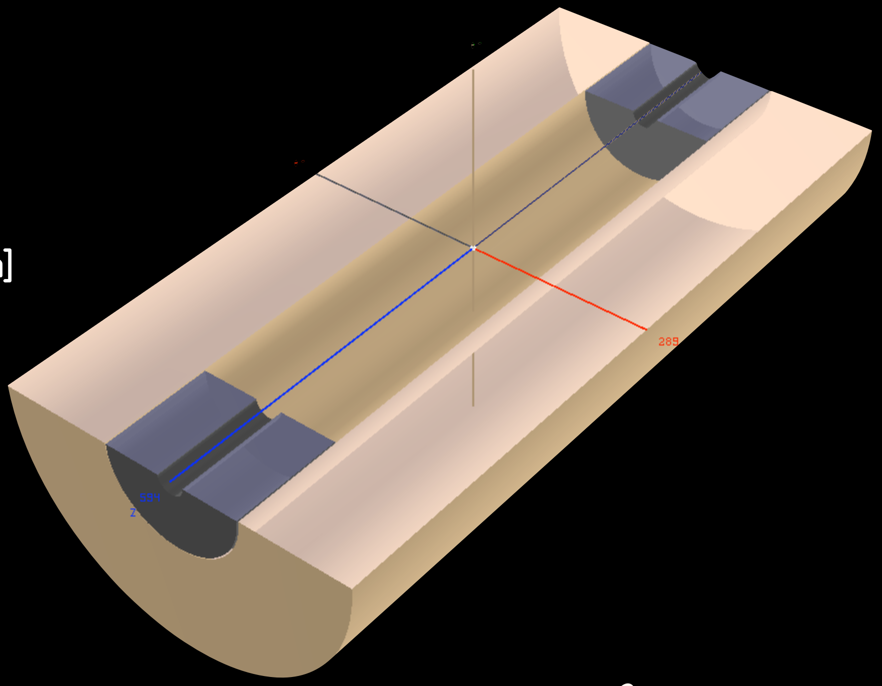
	λ_I[cm]	X_0 [cm]
Iron/Stainless Steel:	17	1.8
Cu Brass:	15.1	1.44

  - Stainless Steel + scintillator (2cm tile thickness) + (6 x λ_I)
    -> 102cm Fe + 37(sampling) x 2cm Sc -> 176cm HaC
    or Fe/LAr (H1/ATLAS type) - H1: $\sigma(E)/E = 12\%/\sqrt{E} \otimes 1\%$ (electron) | $50\%/\sqrt{E} \otimes 2\%$ (pion)
    but almost excluded by modular design - see summary

Calorimeter Details 2

- Hadron Calorimeters - all 6 λ_I

	inner radius	outer radius	half length	end Position ±z (HighQ^2) [cm]	
HaC-Barrel	112	289	594	594	
HaC-insert-2	21	110	88.5	594	(378)



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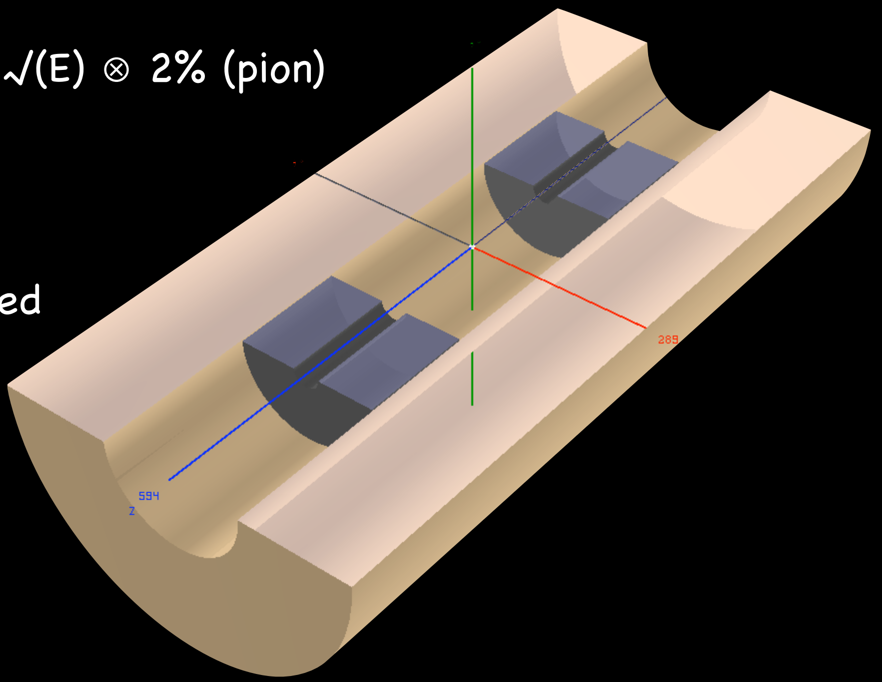
- HaC-insert-2 (movable)
  - Stainless Steel + scintillator and SS + MAPC (inner part) - to be simulated



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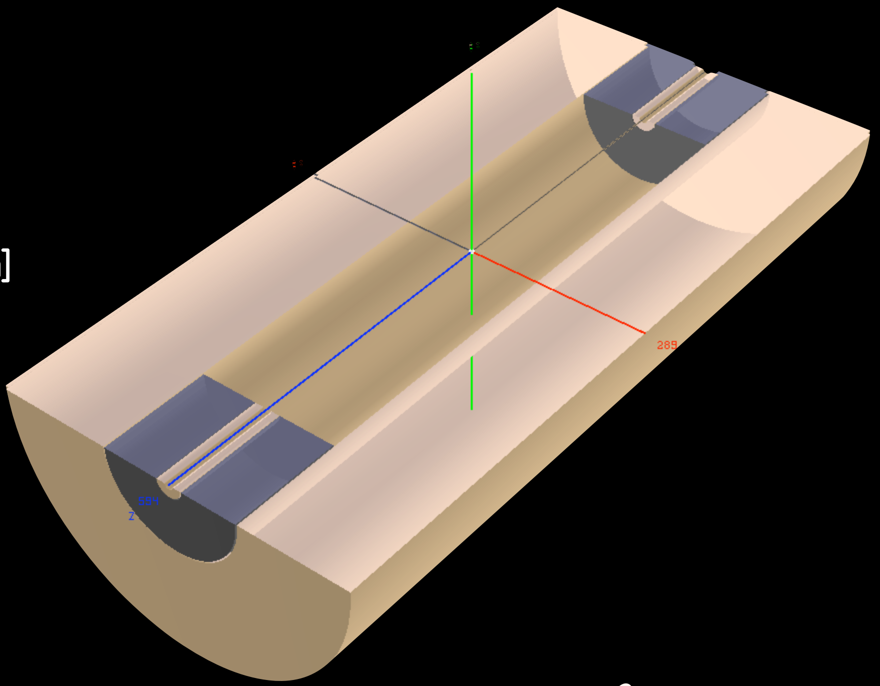
in any case: NO GAPS to adjacent Electromagnetic Calorimeter



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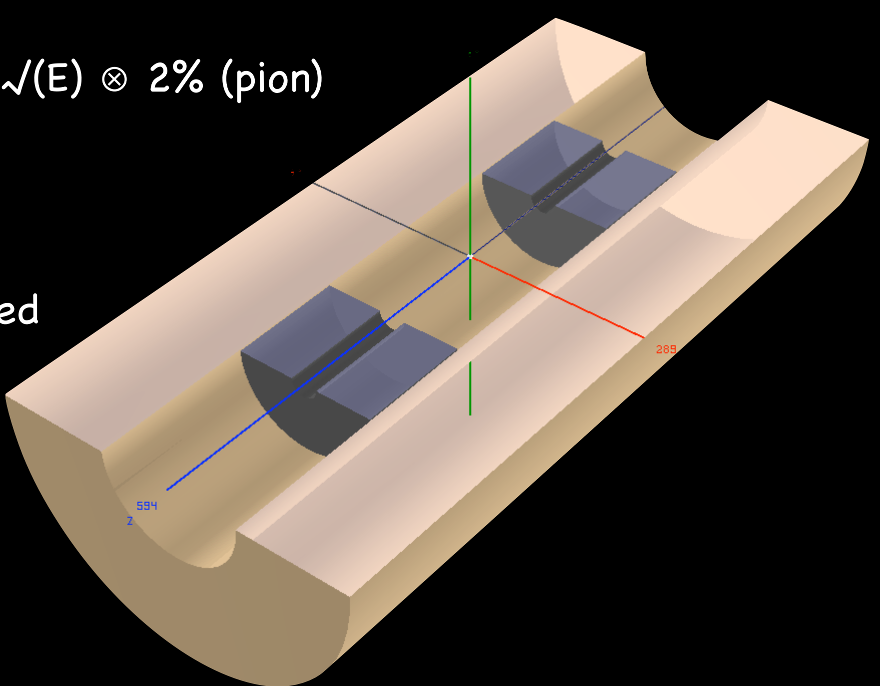
- HaC-insert-1 for LowQ² (removable)
  - SS + Si-Gas Detector R/O (different options - see i.e. Calice developments)
  - given the dimension/samples:
    better performance using Brass & 1cm si-gas detectors -> 9.2 x λ_I
    or SS & 1cm si-gas detectors -> 8.1 x λ_I



HighQ² HaC

Summary Tracker

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- Due to low material budget the multiple interactions shouldn't (or only little) deteriorate $\Delta p_T/p_T^2$ in fwd/bwd regions & low momenta;
  BUT simulations are mandatory taking into account all contributions;
  Asymmetry fwd/bwd tracking
  - different granularity/resolution of trackers fwd/bwd
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- Building the central track detector directly onto the beam pipe (see backup slide)
  - Modul: segment of beam pipe, cones, layers

Summary Tracker

- Acceptance - Tracker - θ (0.9^0 - 179.1^0), η (±4.8) - LowQ²
-   - θ (2.9^0 - 177.1^0), η (±3.7) - HighQ²
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- Building the central track detector directly onto the beam pipe (see backup slide)
  - Modul: segment of beam pipe, cones, layers
  - even less material

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  Asymmetry fwd/bwd tracking
  - different granularity/resolution of trackers fwd/bwd
  - requirements for eA: # of tracks / dense track structures ?

- Building the central track detector directly onto the beam pipe (see backup slide)
  - Modul: segment of beam pipe, cones, layers
  - even less material
  - even better angular acceptance - lightweight design

Summary Tracker

- Acceptance - Tracker - θ (0.9^0 - 179.1^0), η (±4.8) - LowQ^2
- - θ (2.9^0 - 177.1^0), η (±3.7) - HighQ^2
- Due to low material budget the multiple interactions shouldn't (or only little) deteriorate $\Delta p_T/p_T^2$ in fwd/bwd regions & low momenta;
  BUT simulations are mandatory taking into account all contributions;
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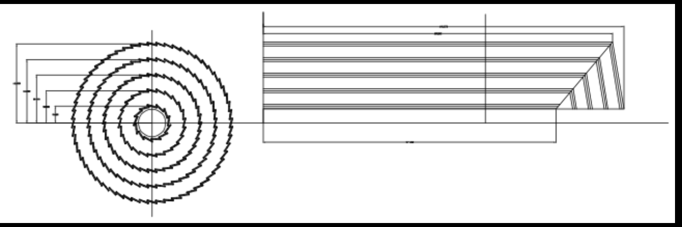

Exercise Track Resolution

Exercise Track Resolution

- i.e. assuming / using (Glückstern relation): $\frac{\sigma(p_\perp)}{p_\perp} = \frac{\sigma(x)}{aBL^2}\sqrt{\frac{720}{N+4}} \cdot p_\perp$ with $a = 0.3\ \mathrm{T^{-1}m^{-1}GeV}$

  N track points on L; length of track perpendicular to field B, accuracy σ(x)

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- track accuracy = 15µm & $\theta = 5^0$ & N_{min} = 90 -> length ~39cm -> $\Delta p_T/p_T^2$ = 0.045 for p_T = 10GeV
- track accuracy = 25µm & $\theta = 3^0$ & N_{min} = 60 -> length ~20cm -> $\Delta p_T/p_T^2$ = 0.34 for p_T = 10GeV

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- track accuracy = 15µm & θ = 3^0 & N_{min} = 110 -> length ~20cm -> $\Delta p_T/p_T^2$ = 0.15 for p_T = 10GeV

Summary Calorimeter

Summary Calorimeter

- Acceptance - Calorimeter - LowQ^2
  - EmC-insert-1 θ (1.1^0 - 178.9^0), η (±4.7)
  - HaC-insert-1 θ (0.9^0 - 179.1^0), η (±4.8)
  - EmC-insert-2 θ (3.2^0 - 176.8^0), η (±3.6)
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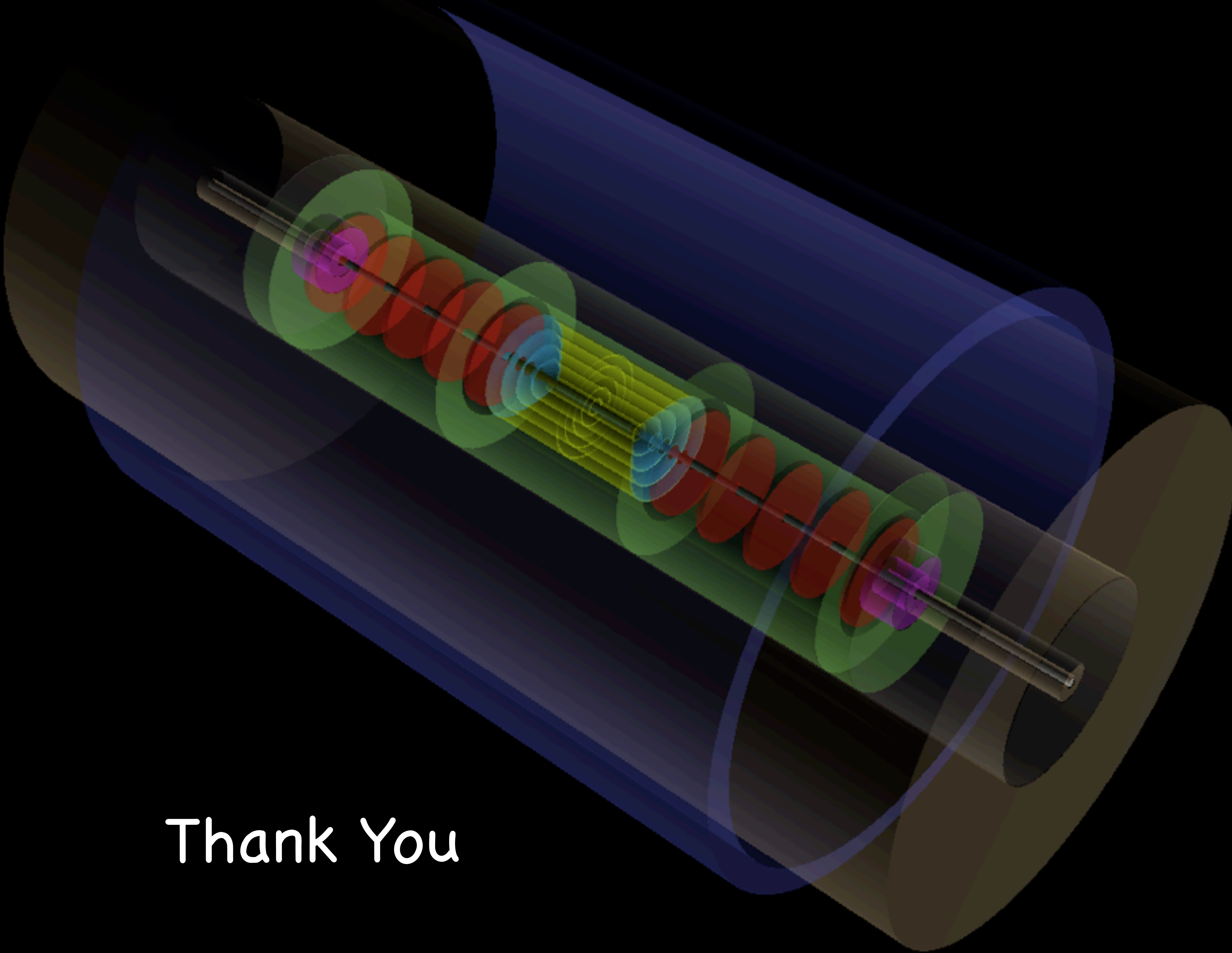
- For both types of Calorimeters:
  fwd/bwd asymmetry taken into account by granularity adjustments
  - transversal & longitudinal

Some Essentials

- Time constraints
- CMS-type logistics => start to assemble the detector "upstairs"
  - ~5 years before you go for the real installation in the cavern
  - ~2-3 years for lowering of moduls (HaC-Barrel see backup), installation, tests

- Dimensions of strong focussing magnets (∅ = 30cm now) and the coil of the 2T-Solenoid have to be defined
  - after detailed machine/physics studies
  - option for an dipol field added to solenoidal field - has to be evaluated

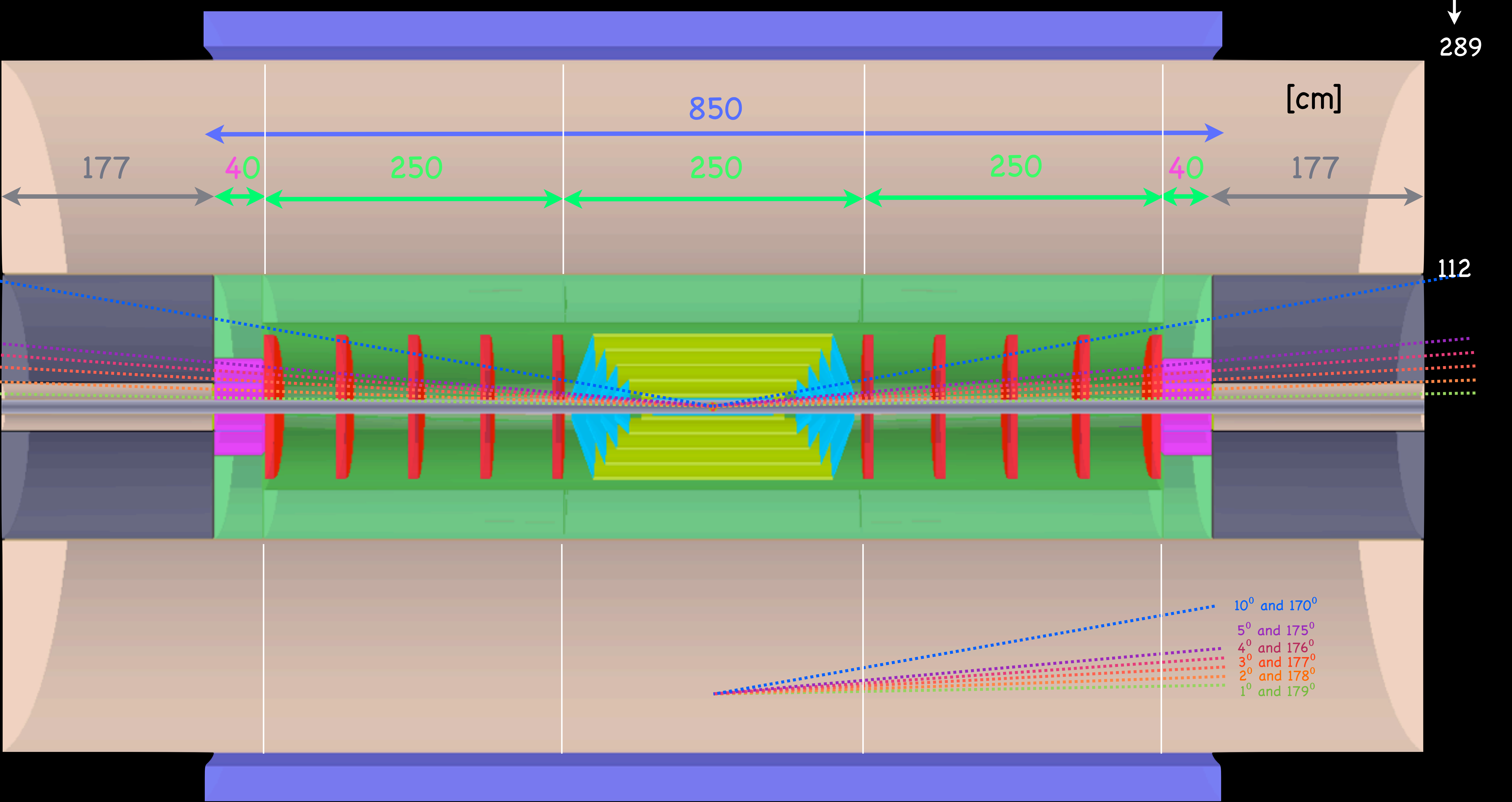
- Background, Collimators (backscattering)
- Manpower - an issue;
  Collaboration with ongoing projects (mainly ILC) a.s.a.p



Thank You

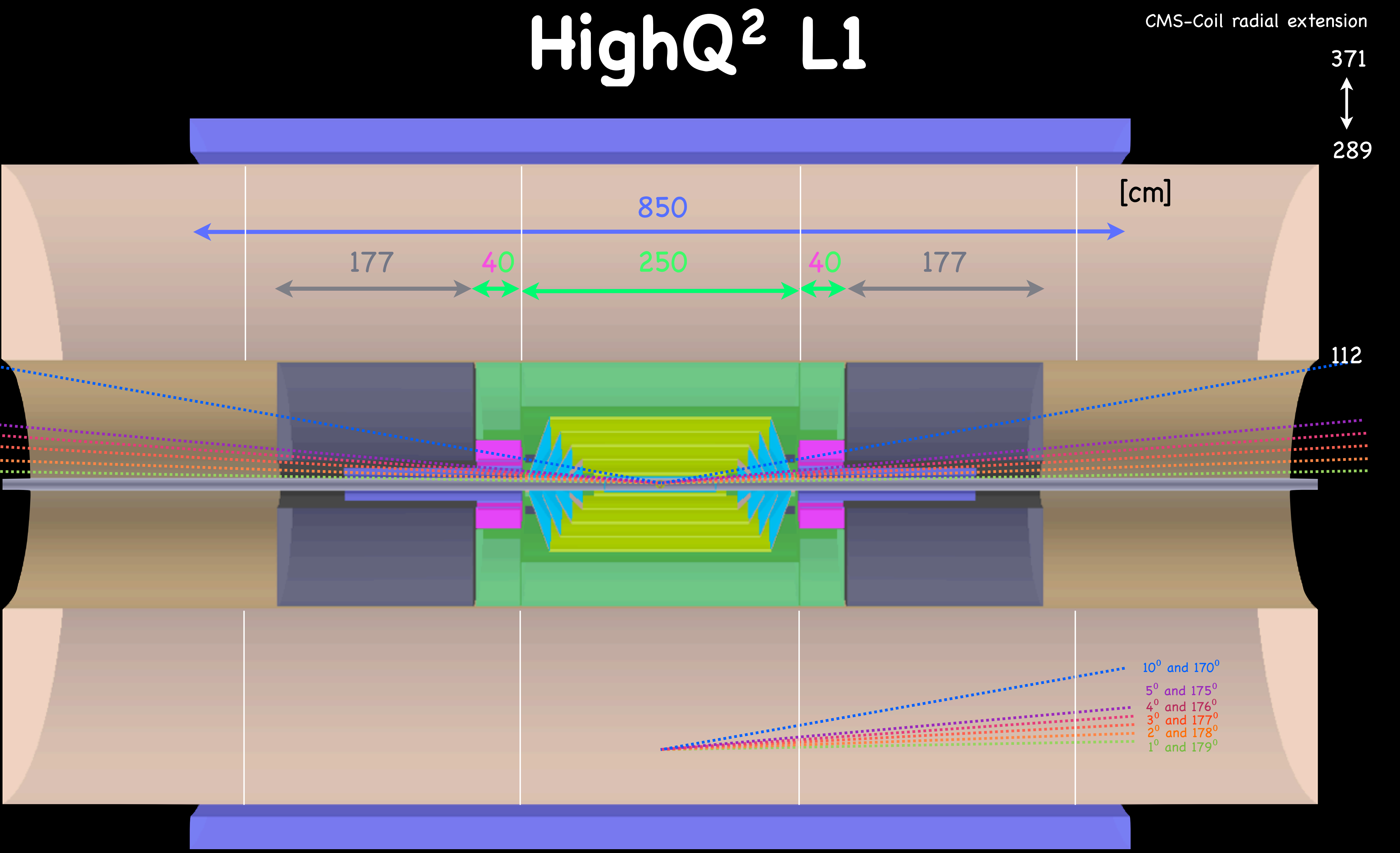
Backup

LowQ^2 L1



CMS-Coil radial extension
371
289
[cm]
850
177
40
250
250
250
40
177
112
10⁰ and 170⁰
5⁰ and 175⁰
4⁰ and 176⁰
3⁰ and 177⁰
2⁰ and 178⁰
1⁰ and 179⁰

HighQ² L1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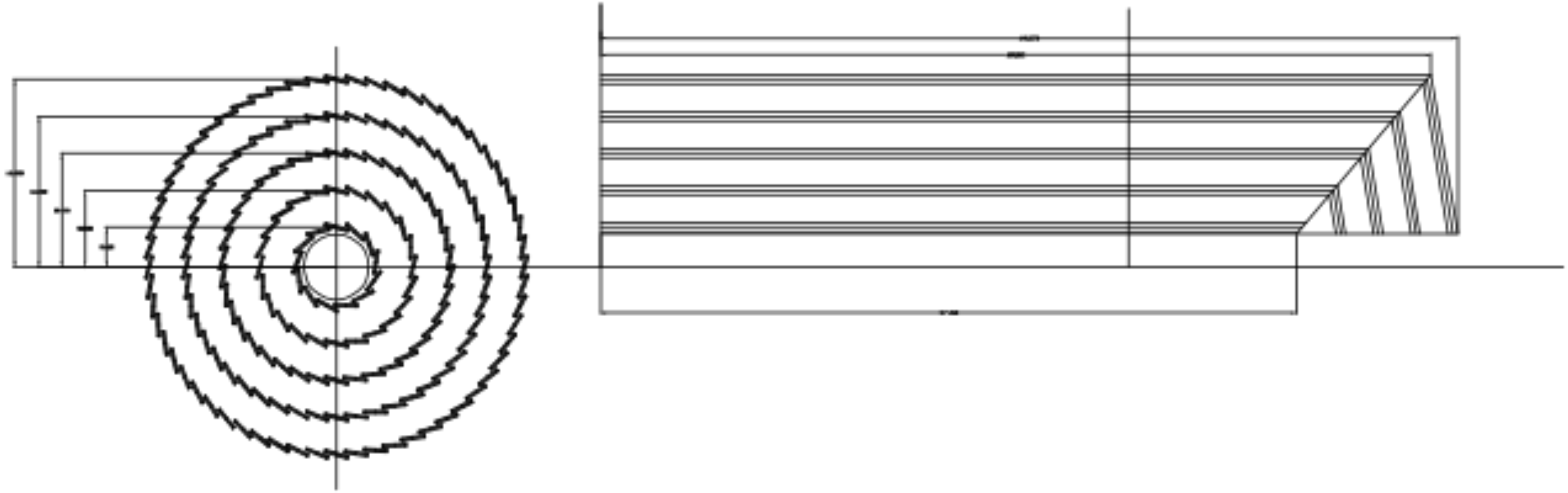
4⁰ and 176⁰
3⁰ and 177⁰
2⁰ and 178⁰
1⁰ and 179⁰

Virtual goal: ATLAS pixel vertex



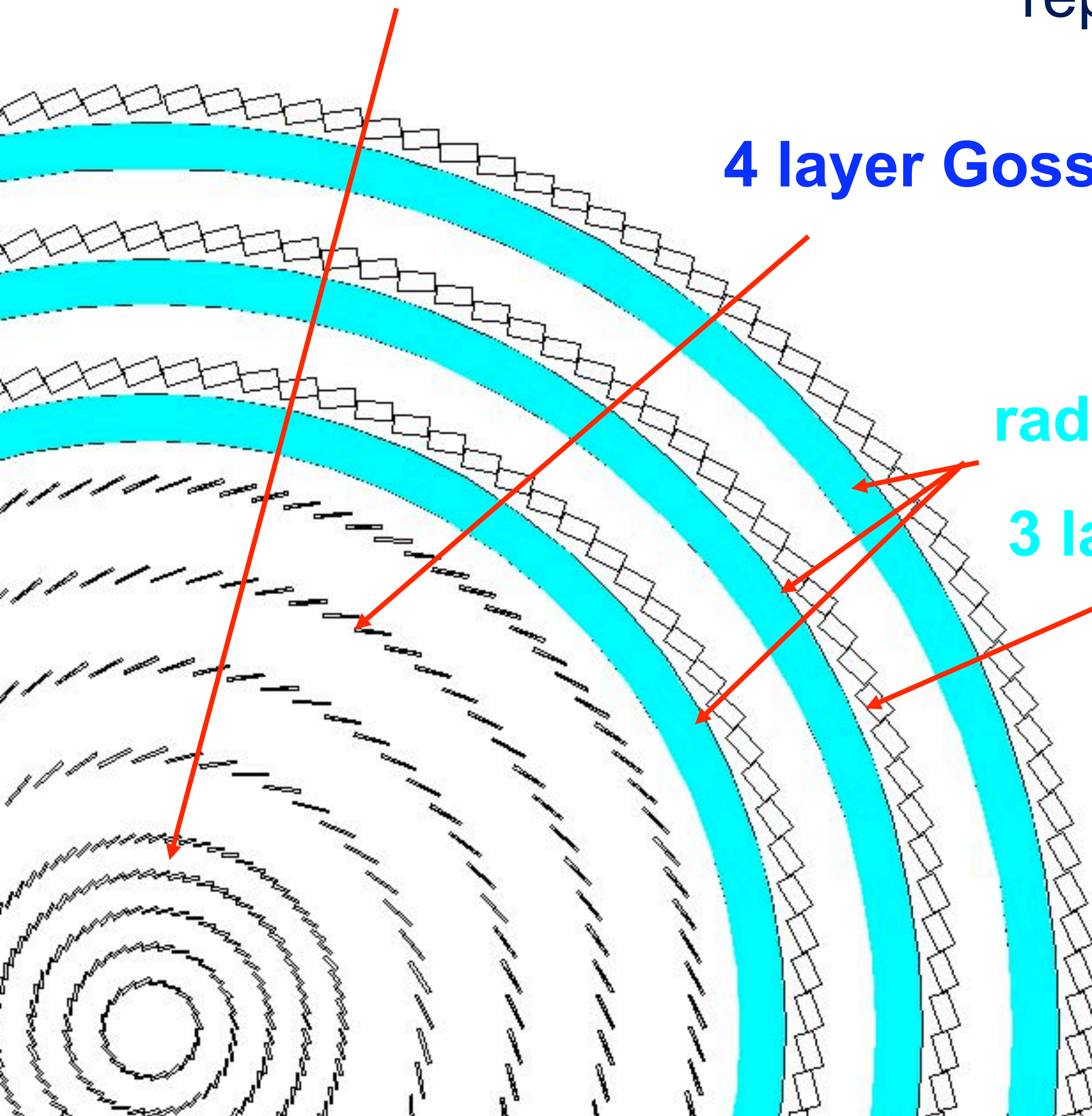
- Ladder strings fixed to end cones
- Integration of beam pipe, end cones & pixel vertex detector
- 5 double layers seems feasible

Vision of:

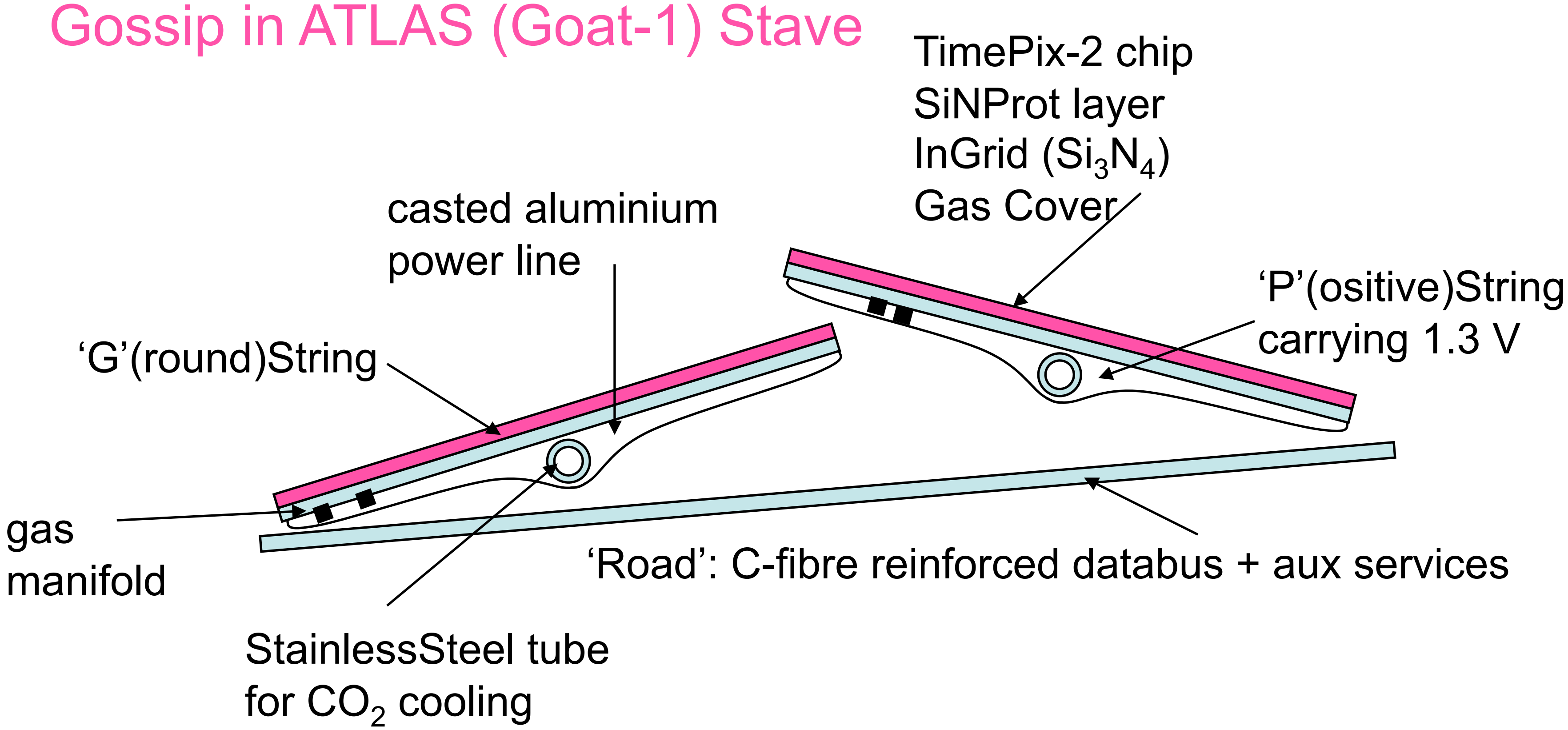
Harry van der Graaf
NIKHEF, Amsterdam

ATLAS Upgrade Workshop
Dec 7, Liverpool, 2006

ATLAS Upgrade: replace Si detectors

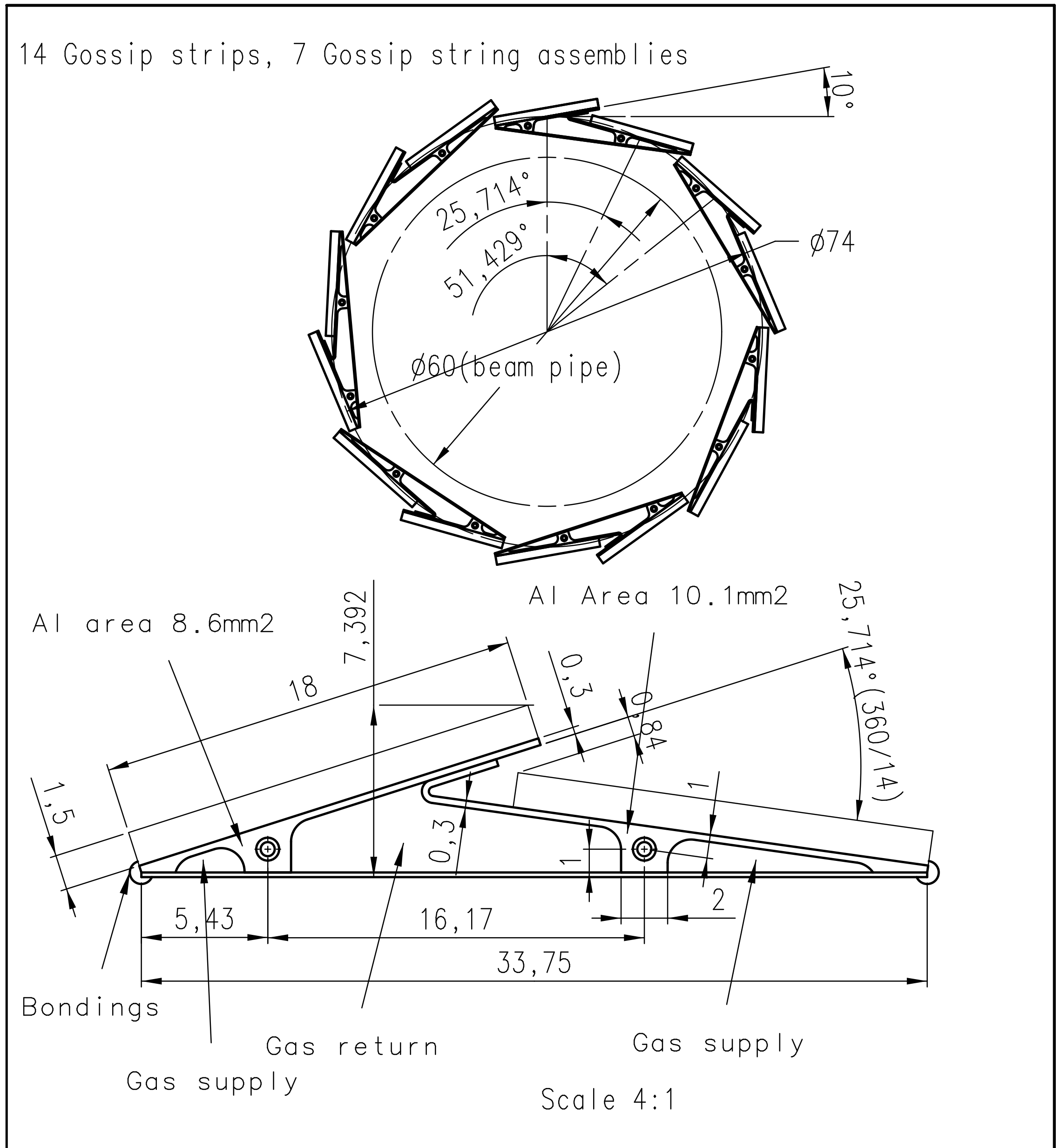


Gossip in ATLAS (Goat-1) Stave



Stiff, light Stave formed by G-string
P-string
Road triangle

- Applied power 0.2 Watt per chip
- Cooling temperature 20°C
- CO_2 Heat transfer: 12000 W/mK
- Glue joints 50 mu
- $\lambda_{aluminium}$=120 W/mK
- $\lambda_{silicon}$=120 W/mK
- $\lambda_{stainless}$=16 W/mK
- $\lambda_{carbonfibre}$=10 W/mK
- λ_{glue}=0.35 W/mK



Proposal!

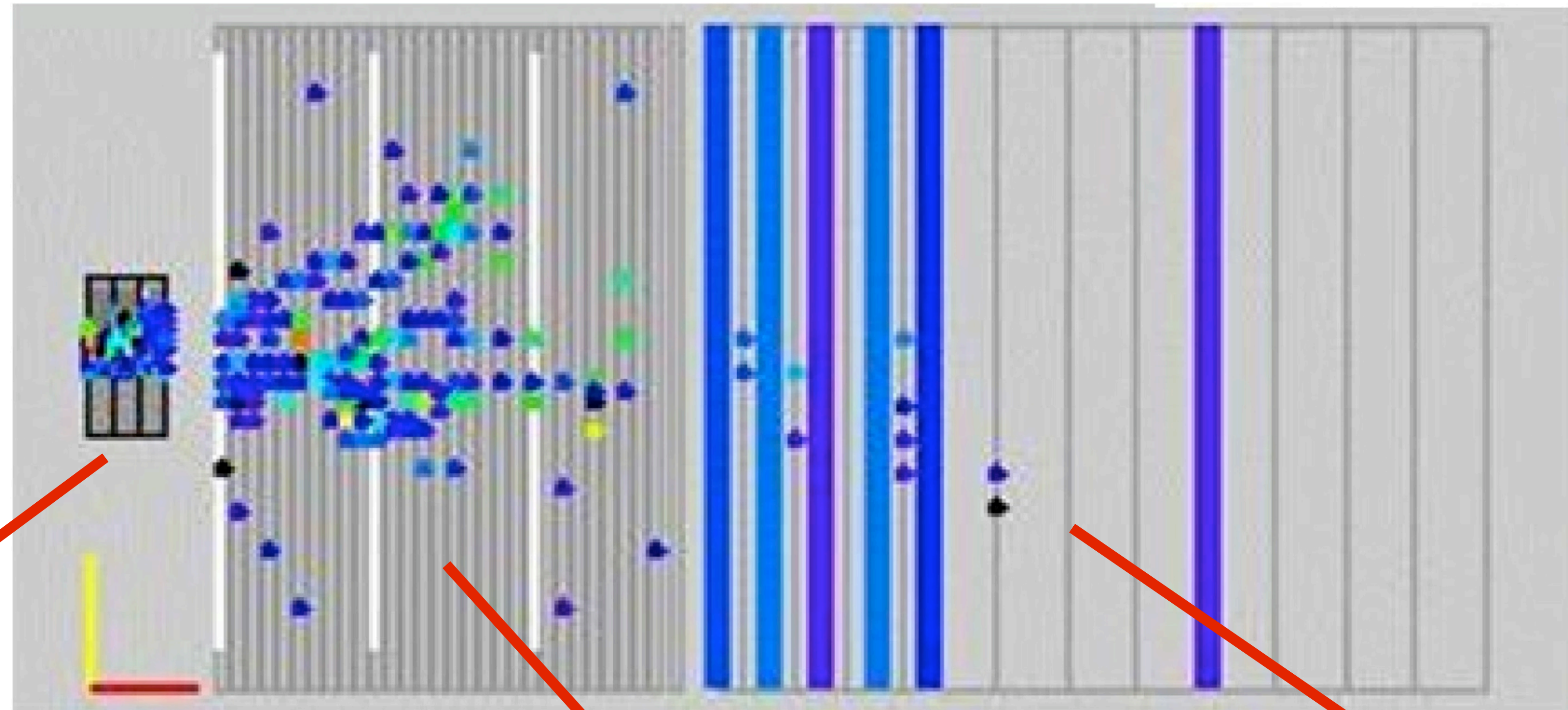
Project: GOAT GOssip in ATlas		Revision	Date / Name
Title: Inner Gossip String Layout		A, B, C, D	
Scale: 1:1	Drawn: BV	Dim. in mm	General tolerances unless otherwise stated according to ISO-2768-mK-E
Date: 23-09-08	Checked:		Geometrical tolerances unless otherwise stated according to ISO-8015-E
NIKHEF — NATIONAL INSTITUTE FOR NUCLEAR PHYSICS, AND HIGH ENERGY PHYSICS, P.O.41882,1009 DB Amsterdam,The Netherlands	BVE	Size: A4	Roughness unless otherwise stated according to DIN 1302
		Identification No.: GTA001	Sheet No: 1 Number of sheets: 1

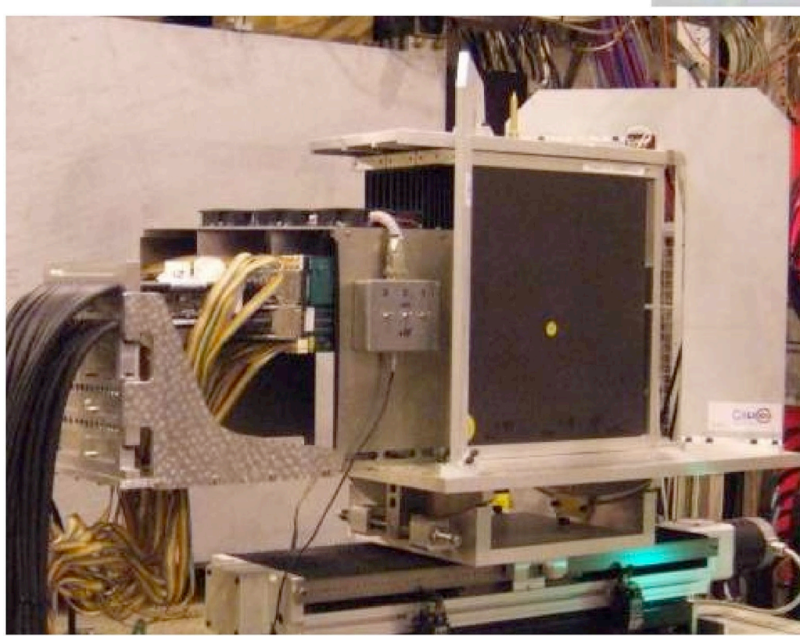
The CALICE Subsystems

- Electromagnetic Calorimeter
  - **Silicon - Tungsten: Si-Pad detectors**
    - MAPS - Option
  - Scintillator-Tungsten
- Hadronic Calorimeter
  - **Analog: Steel - Scintillator tiles with SiPM readout**
  - Digital: Steel - RPC / MicroMegas / GEM
- Tailcatcher:
  - **Analog: Steel - Scintillator strips with SiPM readout**

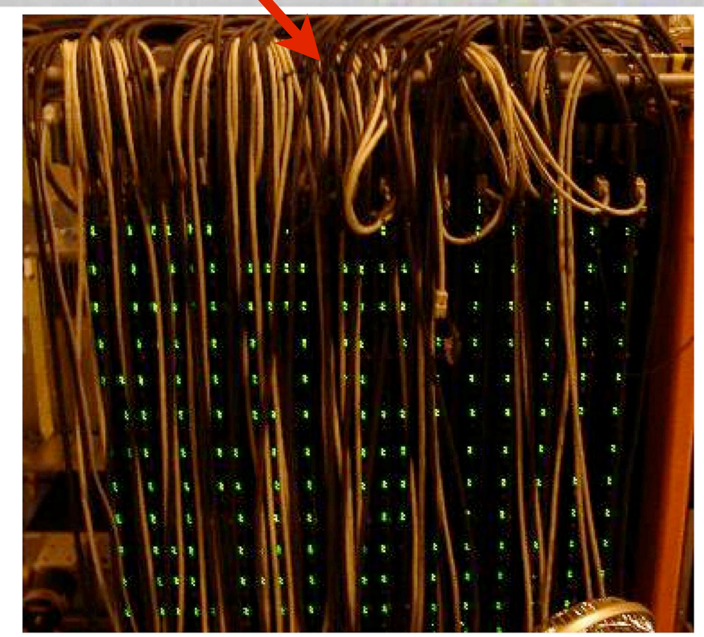
CALICE Calorimeter Setup

- 40 GeV negative pions

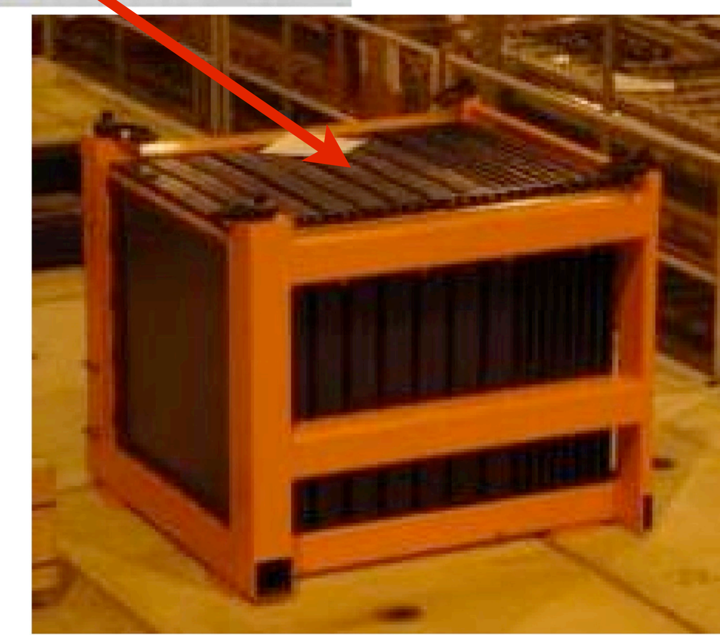




Si-W ECAL
1x1 cm^2 lateral segmentation
30 layers, ~ 0.9 λ, 30 X_0
~ 10 k channels

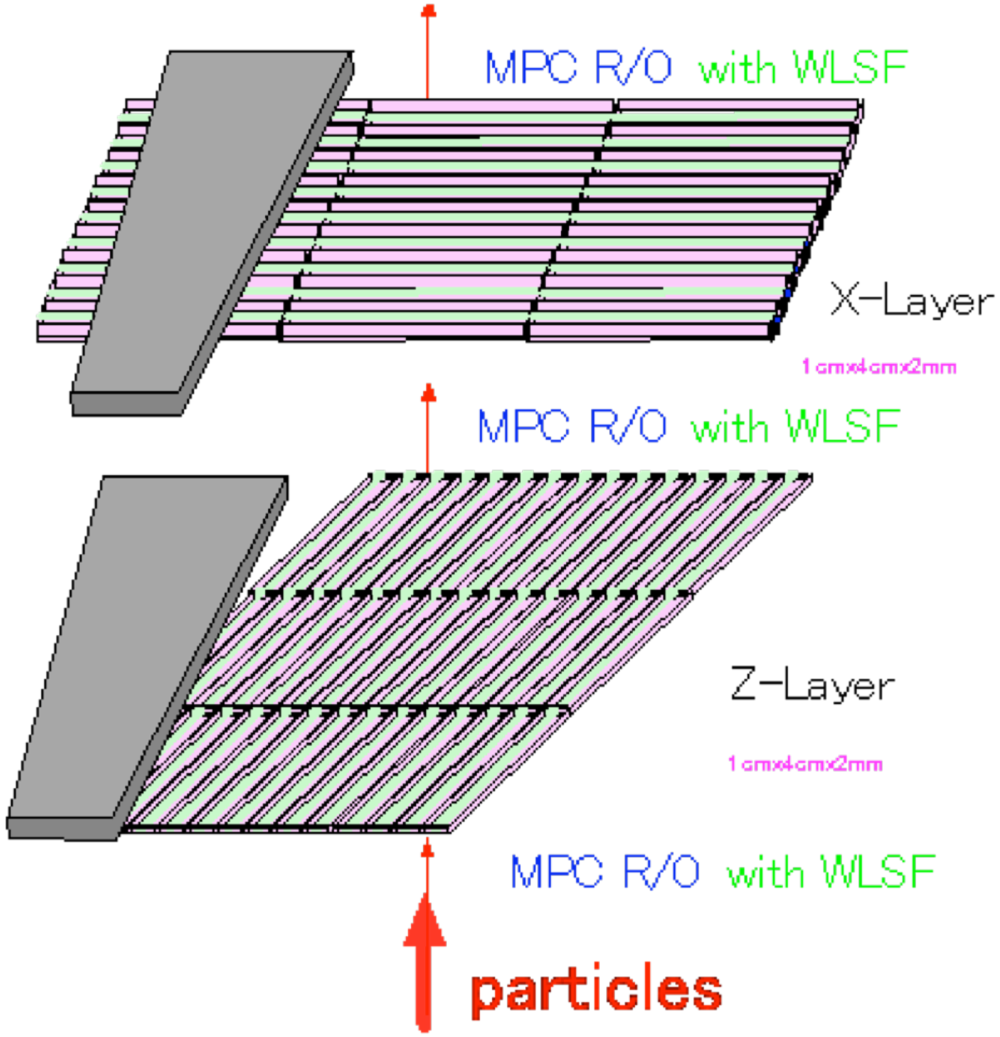


Analog HCAL
3x3 - 12x12 cm^2 lateral segmentation
38 layers, ~ 4.5 λ
~ 8 k channels

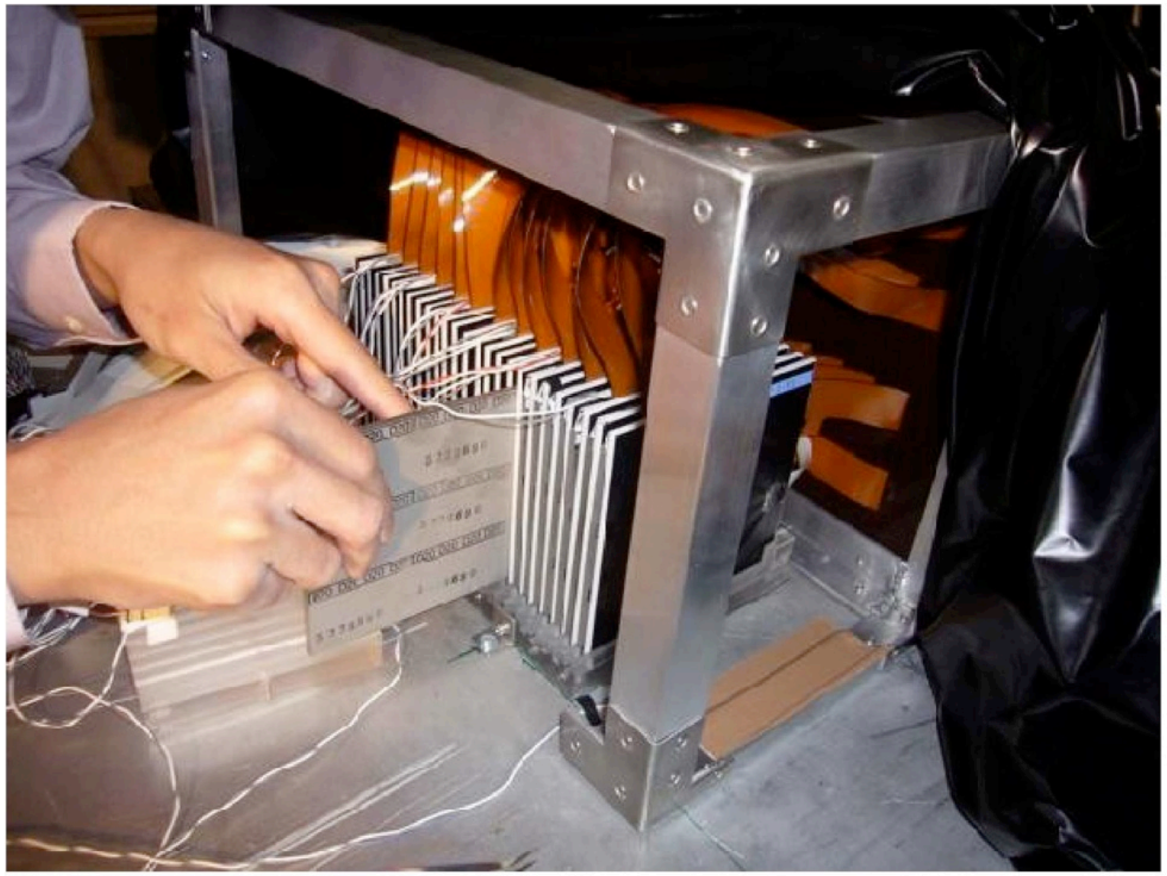


Tail Catcher / Muon Tracker
5 x 100 cm^2 Scintillator Strips
16 layers
~ 300 channels

Changing Setup: Scintillator ECAL



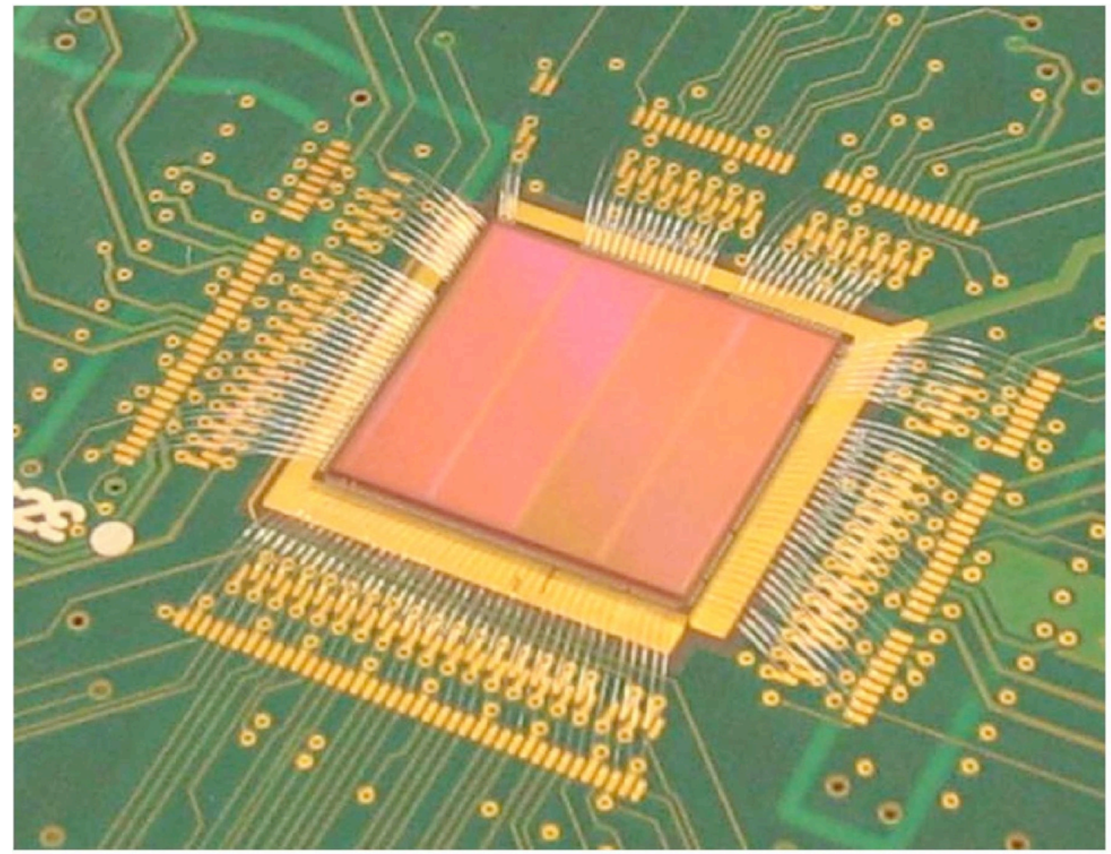
- Tungsten absorber
- Scintillator with MPPC readout
  - 1 x 5 cm^2 , 3.5 mm thick scintillator strips
  - embedded wavelength shifting fiber
  - three different scintillator types tested

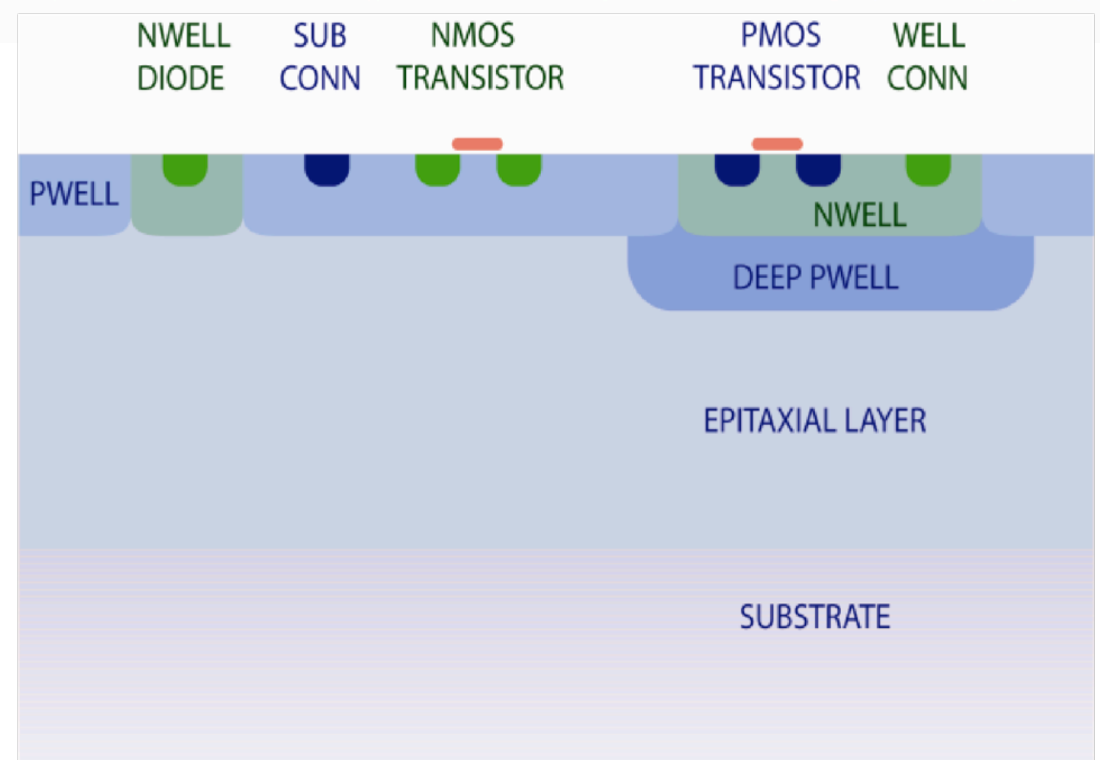


- First tests in DESY test beam in 2007
- Now installed in CALICE setup at FNAL, replacement for Si-W ECAL, beam time starting tomorrow

New Si-W Concepts: MAPS

- MAPS instead of Si Pads:
  - Determine Energy by counting particles, not by measuring energy deposit
  - Extreme granularity needed to preserve linearity
    - 50 x 50 μm^2 pixels
    - binary readout
    - electronics integrated into pixel

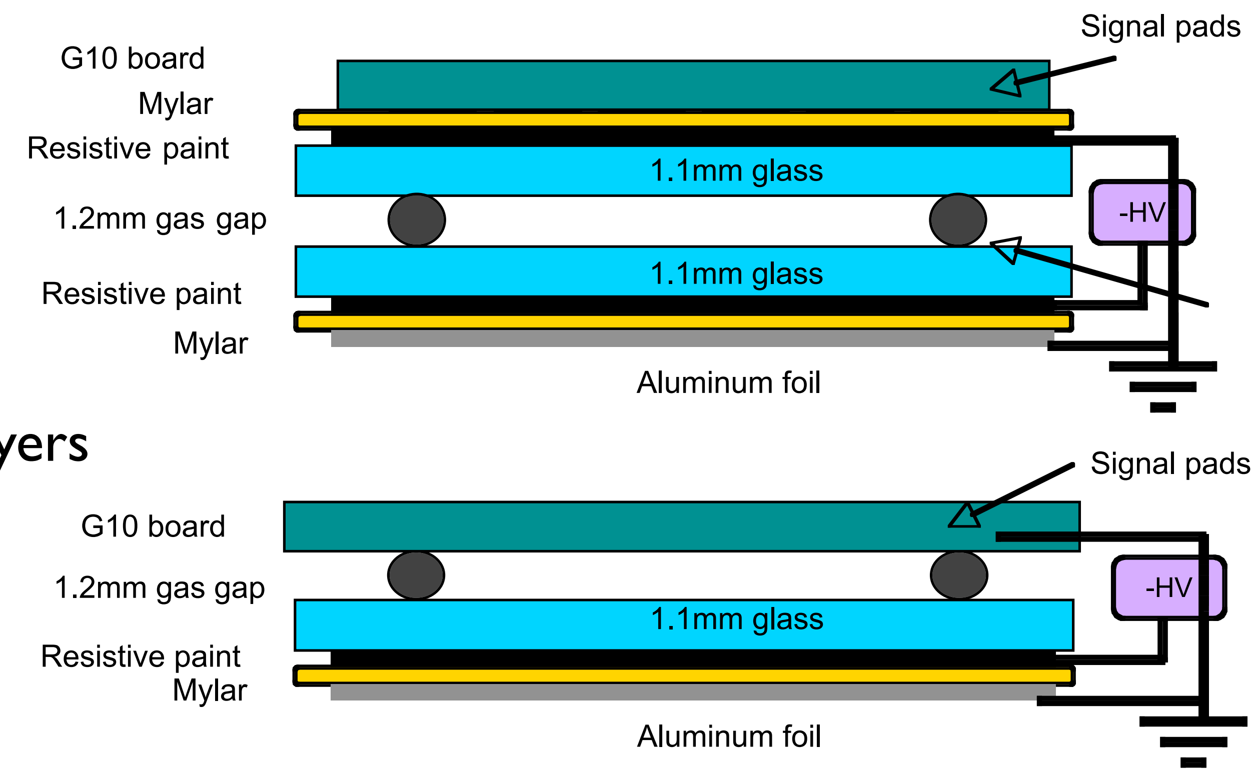




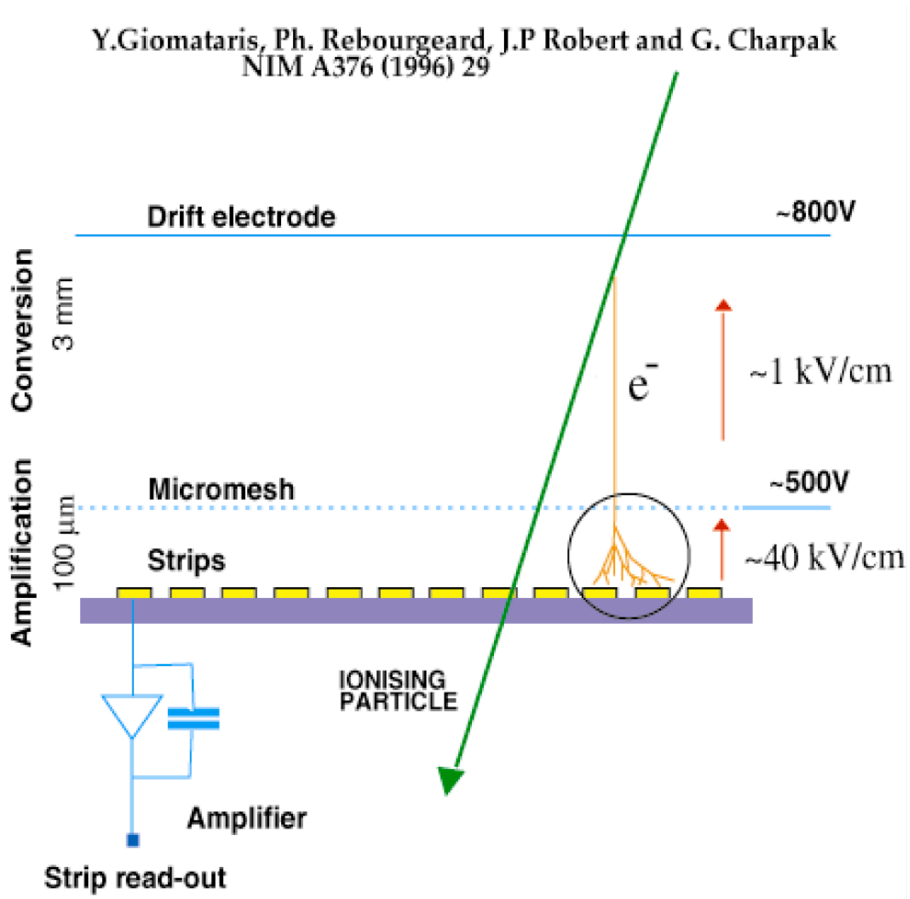
Changing Setup: Digital HCAL

- Digital (or semi-digital) HCAL
  - ~ 1 x 1 cm² pads
  - gas detector readout, different technologies being explored

RPCs:
1 or 2 glass layers



MicroMegas



GEM (Double GEM, ThickGEM, ...)